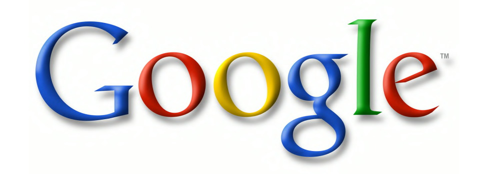
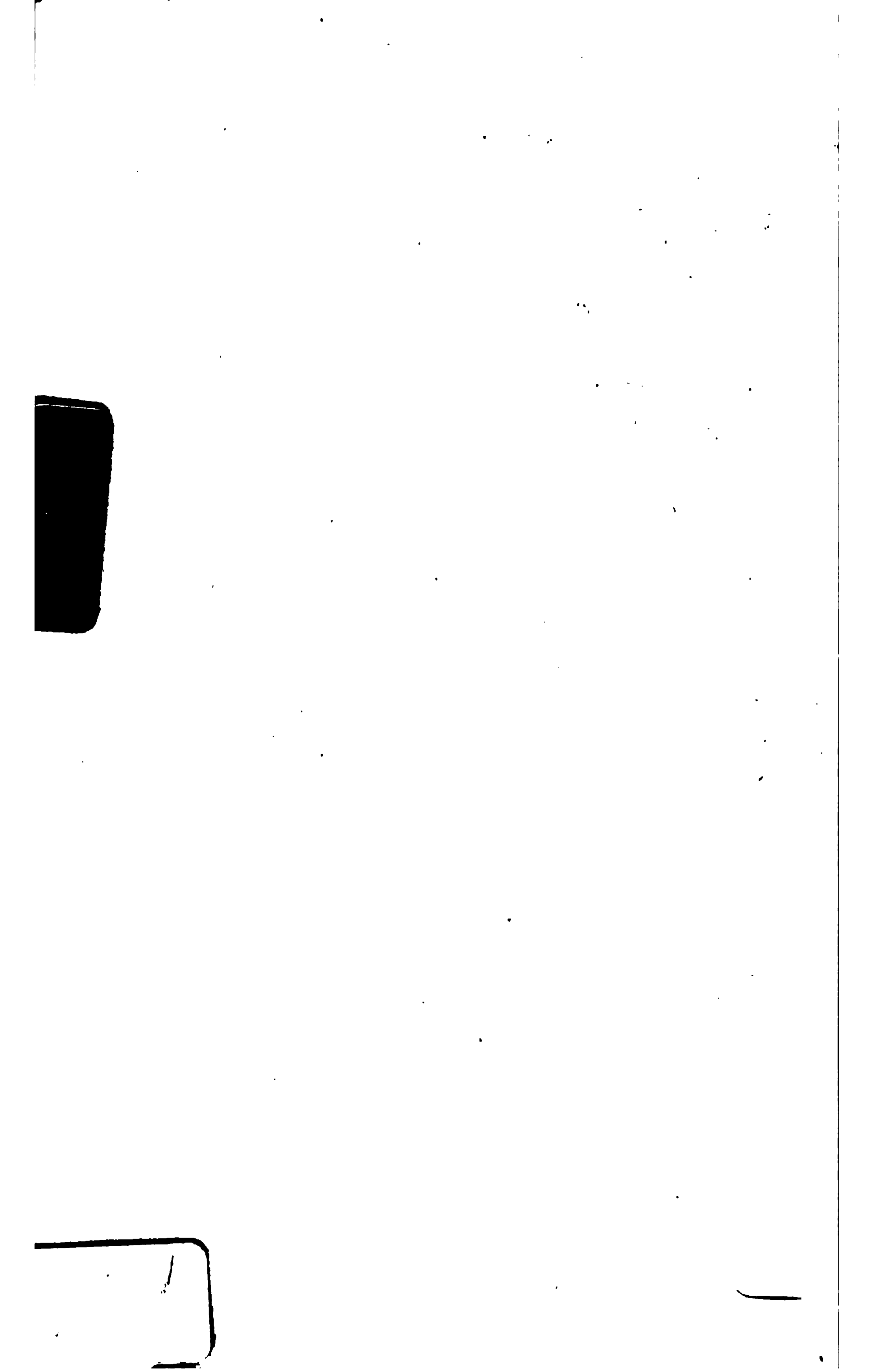
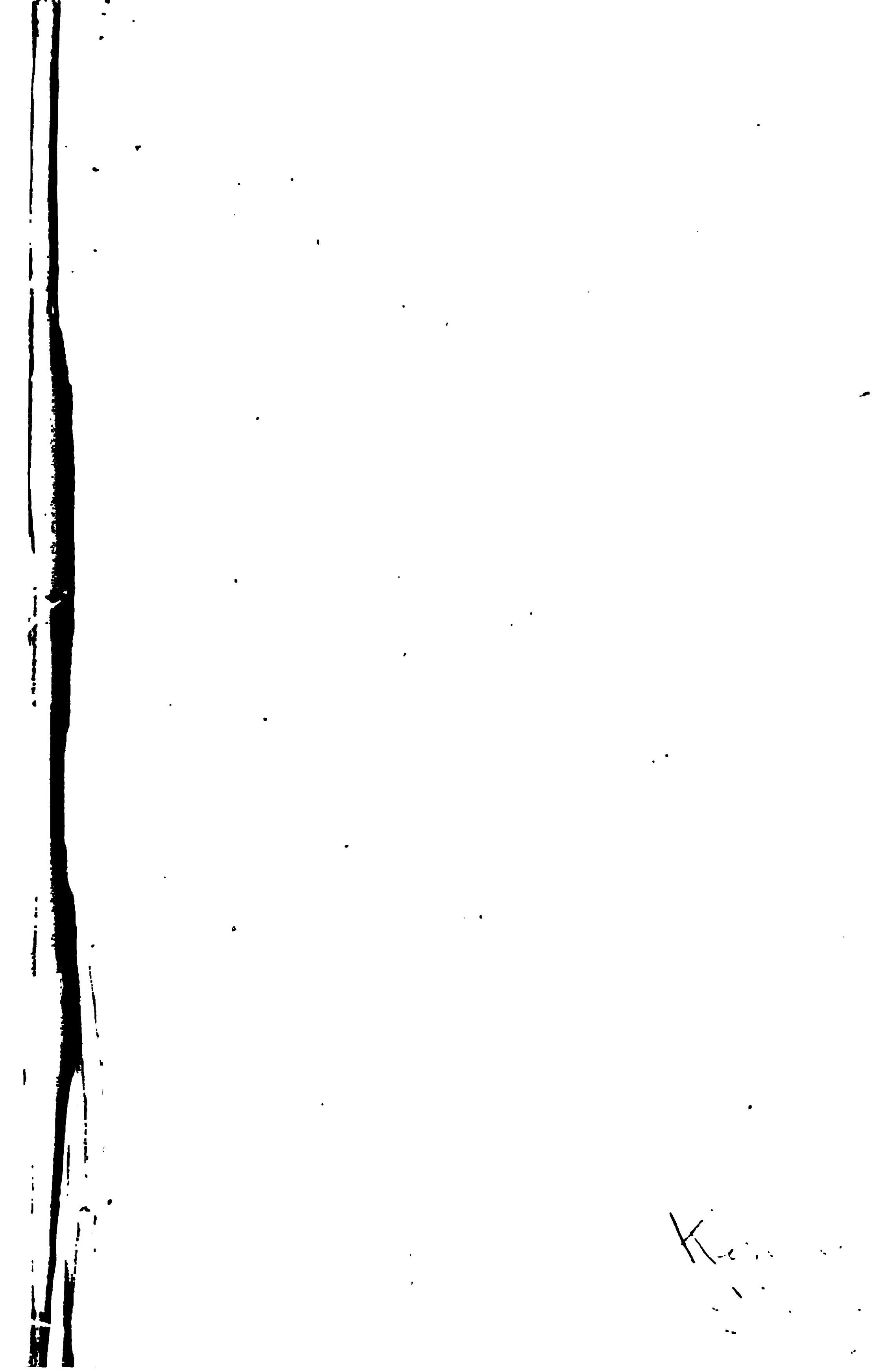
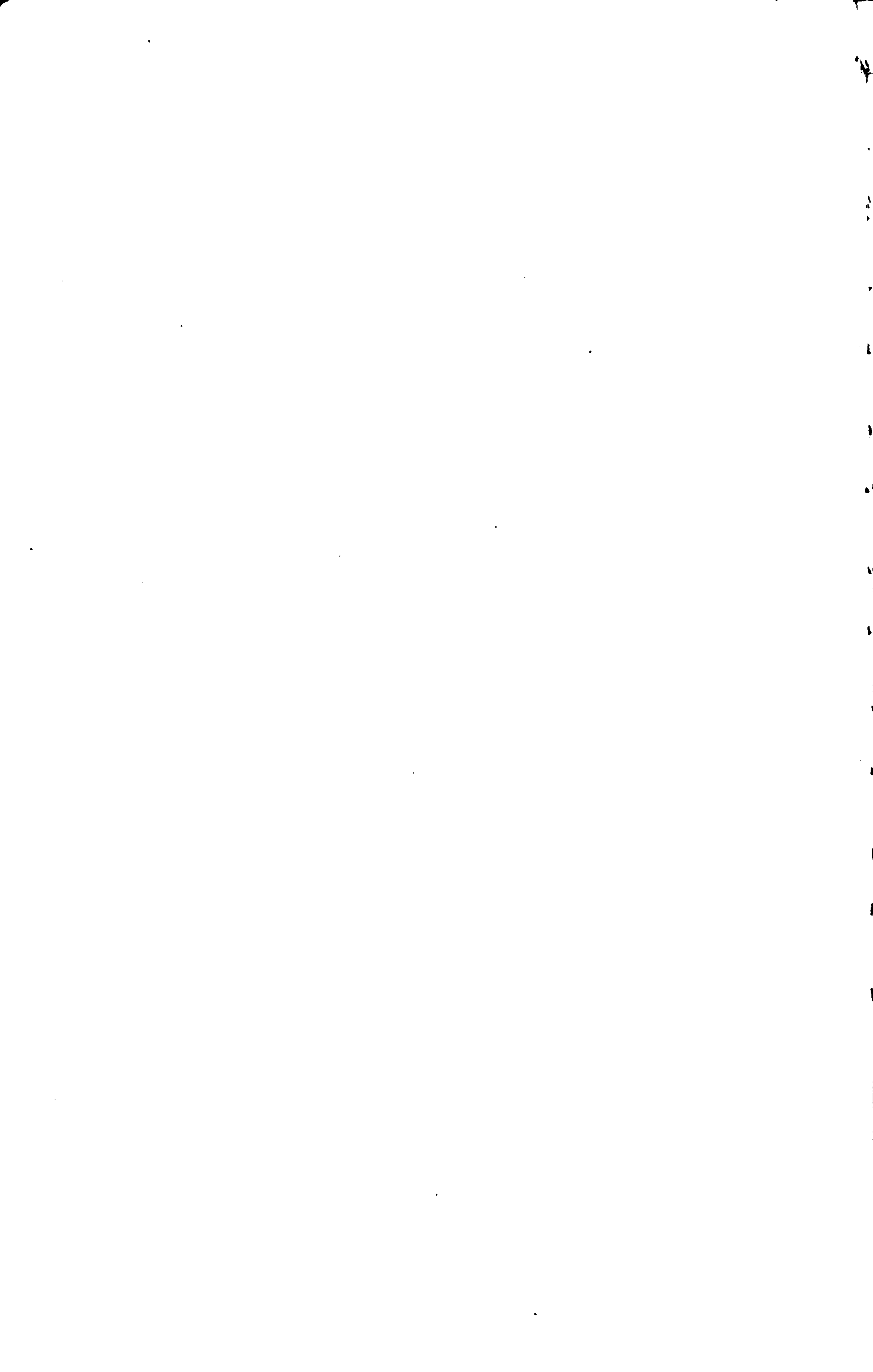


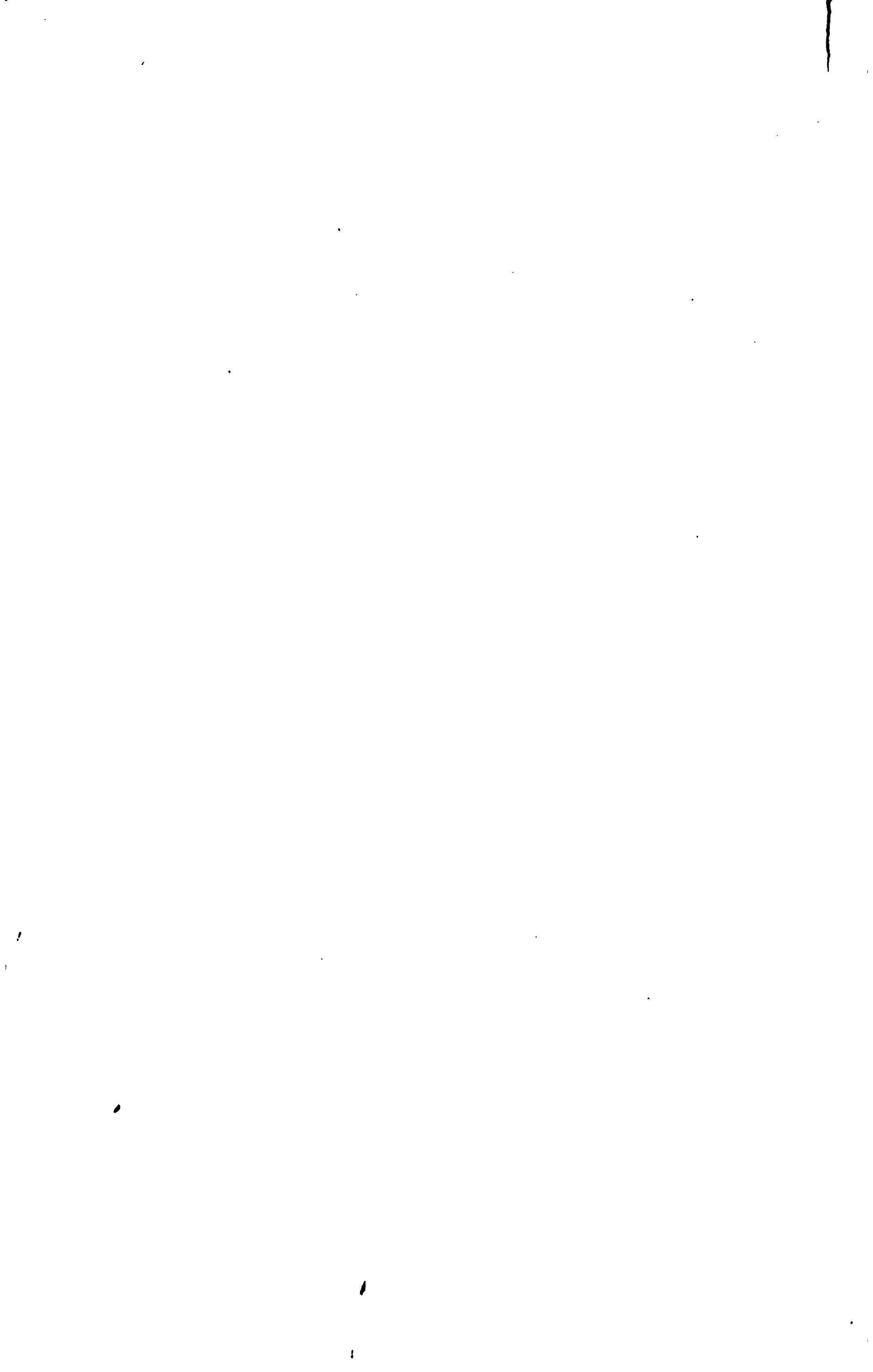












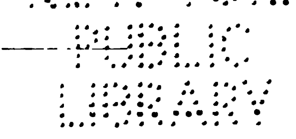
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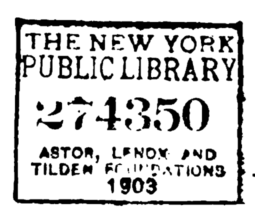
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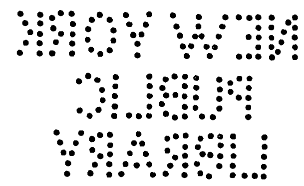
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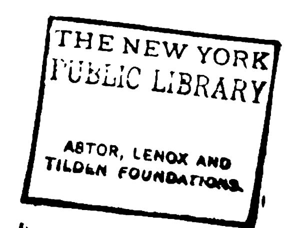
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NEW BRYOZOANS FROM THE COAL MEASURES OF KANSAS AND MISSOURI.

Contribution from the Paleontological Laboratory No. 52.

BY AUSTIN F. ROGERS.

With Plates I, II, III, IV.

THE bryozoans occurring in the Coal Measure rocks have received but comparatively little attention. In the faunal lists of the horizons the information concerning the bryozoans is usually of the most meager character. Although they are small and often poorly preserved, the difficulties in the way of their satisfactory determination are but little if any greater than with other groups of fossil invertebrates. Their characters are, as a rule, extremely constant. It is the writer's conviction that the value of bryozoans in the correlation of the above-mentioned rocks is as great as that of any other group, and consequently that they should receive more attention.

Forty-two well-defined species have been described from the Coal Measures of the United States, of which number Ulrich is the author of twenty-six; Foerste, six; Meek, five; White, two; Prout, Swallow, and Worthen, one each; to which the author here adds twenty-two.

Unless otherwise stated, the specimens described in this paper were collected by the writer, except those from Topeka, Kan., which were obtained by Dr. J. W. Beede, to whom I am greatly indebted for this and other favors.

In the classification and in the sequence of the parts of the descriptions, Ulrich, the authority on American paleozoic bryozoa, has been closely followed.

BATOSTOMELLIDÆ Ulrich.

***Stenopora spinulosa*, n. sp.** Plate IV, fig. 5.

Zoarium a thin, expanded crust, attached to a brachiopod (*Derbya crassa*), from which proceed several cylindrical stems, 2 mm. in diameter. Surface montiferous, exhibiting slightly elevated monticules,

occupied by apertures a little larger than the average. Zoecial apertures angular to subangular, with thin walls, six in 2 mm. Strong acanthopores at the cell angles. Numerous very small acanthopores occur along the cell walls. Often strong acanthopores are found here, too. Internal characters unknown.

Position and locality: Upper Coal Measures; Melvern, Osage county, Kansas. Collected by Judge E. P. West. Type in the University of Kansas Museum.

This species is very similar to *S. ohioensis* Foerste. The strong acanthopores are more numerous and there is a greater contrast between the large and the small acanthopores. There are six instead of ten apertures in a space of 2 mm. It may be a well-marked variety of *S. ohioensis*, but it is believed that these differences, together with the zoarial characters and the montiferous surface, justify its independent existence as a distinct species.

Stenopora spissa, n. sp. Plate IV, figs. 4–4*b*.

Zoarium a cylindrical, dichotomously dividing stem, varying from 4 to 8 mm. in diameter. Surface smooth, not montiferous. Zoecial apertures subcircular, with rather thick interspaces, about six occurring in 2 mm. Zoecial tubes thin and polygonal in the immature region, making an abrupt bend to the surface, where the walls are greatly thickened. Walls not distinctly moniliform, but often an elongated swelling is noticed just after the walls enter the mature region. Diaphragms apparently absent. Acanthopores small, very numerous, all the same size, usually with two rows on the cell walls.

Position and locality: Near the summit of the Upper Coal Measures; Howard, Elk county, Kansas. Collected by Mr. Carmine Ross. Type in University of Kansas Museum.

Resembles *S. ohioensis* Foerste, but the acanthopores at the cell angles are no more prominent than those on the cell walls. Of internal characters, the thickened zoecial walls in the mature region and the absence of diaphragms distinguish it from that species.

CYSTODICTYONIDÆ Ulrich.

Cystodictya inequimarginata, n. sp. Plate I, figs. 2–2*b*.

Zoarium a long stipe, dichotomously dividing at frequent intervals. Branches acuminate-ovate or subcircular in cross section, about 1 mm. wide and 0.75 mm. thick. Non-poriferous margin narrow and sharp on one side; rather wide and rounded on the other. Zoecial apertures much elevated in unworn specimens, small, subcircular, separated longitudinally by about twice their diameter; arranged in three or four linear series. In a space of 3 mm. six apertures occur in the row nearest the wider margin, while eight occur in the same distance in the row nearest the narrow margin. Apertures also quite regularly

arranged in diagonal series, about four in 1 mm. Between the cell ranges obscure longitudinal ridges often occur.

Position and locality: Upper Coal Measures; Lawrence, Kan., and Kansas City, Mo. Type in author's collection.

C. carbonaria Meek has from seven to nine longitudinal rows of apertures.

***Cystodictya divisa*, n. sp.** Plate III, figs. 5–5*d*.

Zoarium a long, more or less flattened, dichotomously dividing stem. Stem acutely elliptical to subcircular in cross-section, 0.8 to 1.1 mm. wide, and 0.6 to 1 mm. thick. Zoecia in four alternating ranges. Apertures rather large, subcircular, probably pustuliform, with a fairly well-developed lunarium seen in sections. Eight or nine apertures occur in a space of 5 mm. In breaking the rock in which they occur, the stems divide along their median plane into two parts or halves, each of which was at first mistaken for the complete zoarium. The poriferous side of the hemibranch adheres to the rock, and its characters can only be judged by thin sections. The non-poriferous surface is flat and occupied by longitudinal striations and by concentric undulations, the latter being similar to those on *Chainodictyon* Foerste. The non-poriferous margins of this surface are rather wide.

Position and locality: Upper Coal Measures; Kansas City, Mo. Type in author's collection.

Differs from the preceding species in having the margins of the branches equal and in dividing along the median planes of the branches.

RHABDOMESODONTIDÆ Vine.

***Streblotrypa ulrichi*, n. sp.** Plate I, figs. 3, 3*a*.

Zoarium a long, slender, cylindrical stem, 0.8 to 1 mm. in diameter, dichotomously dividing at varying intervals. Zoecial tubes long, almost vertical in the middle of the axial region, approaching the surface gradually, and increasing slightly in size at the same time. No inferior hemisepta were observed. Zoecial apertures ovate, surrounded by a thin peristome, highest at the anterior border. Arranged in alternate longitudinal rows between thin, slightly undulating ridges which unite with the peristomes and are about 0.15 mm. apart. Interapertural spaces slightly depressed, and occupied by the mouths of from four to eight small pores arranged in two rows. The typical number of mesopores is six. Measuring longitudinally, eleven apertures occur in a space of 5 mm.; diagonally, four in 1 mm. It requires about twelve rows to encircle the stem.

Position and locality: Upper Coal Measures; Lawrence, Scranton, Topeka, Cottonwood Falls, and ten miles north of Manhattan, Kan.; also in the Permian at Grand Summit, Kan. Type in University of Kansas Museum.

Closely resembles *S. nickelsi* Ulrich from the Chester group. Our species is larger, has a fewer number of mesopores, the ridges separating the ranges are undulating, and the zoecial apertures are a little larger. The internal characters are much like those of Ulrich's species. As far as I know, this is the first mention of the genus in the Coal Measures of America.

Specific name in honor of Mr. E. O. Ulrich, of Newport, Ky., the authority on American paleozoic bryozoa.

Streblotrypa striatopora, n. sp. Plate IV, fig. 1.

Zoarium a dichotomously dividing cylindrical stem, from 1 to 1.5 mm. in diameter. Zoecial apertures arranged alternately in longitudinal series, about six in 3 mm. The diagonal arrangement is usually more noticeable, with five apertures in 2 mm. No longitudinal ridges between the rows. Zoecial apertures subcircular to elliptical, about 0.2 mm. long, surrounding spaces slightly elevated, but without peristomes. Whole surface occupied by numerous small, more or less elongated, mesopores, which are usually arranged in longitudinal series, their lateral walls giving them a decidedly striate appearance. The striations are undulating, and are more prominent in slightly worn specimens. The internal characters are but imperfectly shown in the sections made. The zoecial tubes are short. No hemisepta were observed.

Position and locality: Upper Coal Measures; Kansas City, Mo., and Lawrence, Kan. Type in author's collection.

This species is quite like *S. multiporata* Ulrich, from the Waverly group, of Ohio, but presents the following differences: The zoecia apertures are larger, the mesopores are smaller, and the longitudinal arrangement of the same is more prominent.

FENESTELLIDÆ King.

Fenestella hexagonalis, n. sp. Plate I, figs. 4, 4*a*.

Zoarium a reticulate expansion; size unknown. Branches slender, somewhat flexuous, 0.3 mm. wide, nineteen in a space of 1 cm. Dissepiments short, rounded, much depressed, almost as wide as the branches. Fenestrules subelliptical, slightly constricted in the middle by the zoecia mouths, 0.4 mm. by 0.2 mm., twelve in 1 cm. Carina prominent, subangular, bearing a row of rather large, flattened nodes, usually placed so that there is one opposite each dissepiment. Zoecia in two alternating ranges, seventeen in 5 mm. Apertures comparatively large, elevated, a little more than their diameter apart, usually three to a fenestrule. Rarely is one situated at the end of a dissepiment. On the reverse the branches are more flexuous and subangular. Both they and the dissepiments bear a single row of small,

obscure nodes. The fenestrules are more or less hexagonal in outline.

Position and locality: Upper Coal Measures; Topeka, Kan. Type in University of Kansas Museum.

The reverse side resembles that of *Fenestella flexuosa* Ulrich, but the obverse side of that species is quite different from that of ours. The cell apertures of *F. flexuosa* are more numerous and closer together. Differs from all other species of the genus in the hexagonal appearance of the fenestrules on the reverse side.

***Fenestella dentata*, n. sp.** Plate I, figs. 5, 5*a*.

Zoarium a reticulate expansion; size unknown. Branches straight, rather slender, 0.4 mm. wide, eight in a space of 5 mm. Dissepiments short, depressed, about one-half as wide as the branches. Fenestrules long and narrow, subquadrangular to subellipitical in outline, averaging 0.9 mm. by 0.3 mm., four in 5 mm.; but slightly indented by the encroaching zoecia mouths. Carina rounded, rather strong, bearing a row of prominent flattened, conical nodes, a little more than their diameter apart, twelve in 5 mm. Zoecia in two alternating ranges, about eighteen in 5 mm. Apertures circular, slightly more than their diameter apart, generally arranged so that there are four to each fenestrule. Reverse not seen.

Position and locality: Upper Coal Measures; Topeka, Kan. Type in University of Kansas Museum.

Resembles *F. cestriensis* Ulrich from the Chester group, Illinois, somewhat, but differs mainly in having the carina and the nodes more prominent. This species is distinguished from other Coal Measures species by the narrow, elongate form of the fenestrules.

***Fenestella kansasensis*, n. sp.** Plate I, fig. 6.

Zoarium a rapidly expanding foliar network, of unknown size. Branches rather strong, slightly flexuous, about 0.4 mm. wide, bifurcating at intervals of 3 to 5 mms.; number of branches in 5 mm., eight. Median keel strong, moderately elevated, rounded, somewhat flexuous, bearing a single row of small nodes, 0.5 to 0.6 mm. apart, placed so that two usually occur for each fenestrule. Dissepiments short, depressed, about one-half as wide as the branches. Fenestrules subelliptical to subquadrangular, slightly indented by the encroaching zoecia mouths, averaging 0.8 mm. by 0.4 mm., with about nine in 1 cm. Zoecia in two alternating ranges, eighteen in 5 mm., usually four to each fenestrule. Apertures small, circular, separated by interspaces about the same width as their diameter. Reverse not seen.

A worn specimen, evidently of this species, has wider fenestrules, but in most respects agrees with the type.

Position and locality: Upper Coal Measures; Argentine and Lawrence, Kan. Type in author's collection.

Resembles *F. burlingtonensis* Ulrich, but differs mainly in having more prominent nodes and a greater number of apertures in a given space. *F. burlingtonensis* has seventeen in 1 cm., while our species has twice that number.

Fenestella ovatipora, n. sp. Plate II, fig. 1.

Zoarium a rapidly expanding reticulate expansion; size unknown. Branches lax, slender, rather convex, subcarinate, somewhat flexuous, 0.3 to 0.4 mm. wide, seven occurring in 5 mm.: bifurcating at various intervals, the average being about 3 mm. Median keel obsolete or represented by a raised space between the apertures. Dissepiments rather short, very narrow, and depressed. Fenestrules subelliptical to subquadrangular, quite variable in size, average dimensions being about 1.1 mm. long by 0.4 mm. wide, slightly indented by the encroaching zoecia mouths. Four fenestrules occur in a space of 5 mm. Zoecia in two alternating rows. Zoecial apertures small, ovate, with rather prominent peristomes, about twice their diameter apart, four to each fenestrule, seventeen in 5 mm.

Position and locality: Upper Coal Measures; Kansas City, Mo. Type in author's collection.

All other Coal Measure species of the genus have circular apertures.

Fenestella missouriensis, n. sp. Plate II, fig. 2.

Zoarium a rather rapidly expanding foliar network. Branches rather strong, slightly flexuous, 0.3 mm. wide, ten in a space of 5 mm. Dissepiments short, narrow, rounded, much depressed. Fenestrules subquadrangular to elliptical, 0.6 mm. by 0.3 mm., slightly indented by the zoecia mouths, six and one-half occurring in 5 mm. Carina narrow, rather prominent, slightly flexuous, surface rough but without distinct nodes. Zoecia in two alternating rows, nineteen in 5 mm. Apertures rather large, circular, with slight peristomes, a little more than their diameter apart, three to a fenestrule. Surface covered with obscure longitudinal striæ. Reverse not seen.

Position and locality: Upper Coal Measures; Kansas City, Mo. Type in author's collection.

Polypora aspera, n. sp. Plate II, figs. 3, 3*a*.

Zoarium a foliate expansion of unknown size. Branches rather strong, quite convex, about 0.5 to 0.6 mm. wide, sometimes less just after a bifurcation, six in a space of 5 mm. Surface very much roughened by elevations and depressions. Dissepiments short, rounded, depressed, about one-half as wide as the branches. Fenestrules narrow elliptical or subquadrangular, two in 5 mm., averaging 2 mm. by

0.5 mm. Zoecia in from three to five alternating ranges, these being the extremes between the bifurcations. The prevailing number is four. Apertures small, pyriform, a little more than their diameter apart, about eighteen in 5 mm. Each aperture is situated at the bottom of a depressed area, which is formed by longitudinal ridges between the ranges and horizontal ridges connecting these. A sloping area extends from the anterior end of the depression to the cell aperture which is situated at the posterior end. On the longitudinal ridges spines are regularly arranged, about as numerous as the apertures. Reverse not seen.

Position and locality: Upper Coal Measures; Topeka, Kan. Type in University of Kansas Museum.

The roughened surface of the obverse face serves to distinguish this species from other representatives of the genus in the Coal Measures.

***Polypora flexuosa*, n. sp.** Plate II, fig. 4.

Zoarium a slowly expanding foliar network, of unknown size. Branches slender, quite flexuous, convex, 0.3 mm. wide, ten occurring in a space of 5 mm. Dissepiments very short, nearly as wide as the branches, but slightly depressed. Fenestrules narrow elliptical in outline, averaging 0.7 mm. by 0.25 mm., five in 5 mm. Zoecia in three alternating ranges, which number is reduced to two for a short distance after bifurcating. Zoecial apertures small, subcircular, with thin peristomes, about twice their diameter apart longitudinally, twenty in 5 mm. Space between the cell ranges occupied by single rows of small nodes about as far apart as the apertures. Reverse not seen.

Position and locality: Upper Coal Measures; Argentine, Kan. Type in author's collection.

Differs from other species of the genus in the flexuous character of the branches. No other Coal Measures species has so few zoecia apertures except *P. whitei* Ulrich, from which our species is easily distinguished. Those portions of a branch having two ranges of apertures sometimes possess a faint carina, which gives it the appearance of a *Fenestella*. Here we have another of the numerous links between *Fenestella* and *Polypora*, only one of which has heretofore been described from the Coal Measures, namely, *P. whitei* Ulrich, from Seville, Ill.

***Polypora elliptica*, n. sp.** Plate IV, fig. 2.

Zoarium a reticulate expansion. Branches slightly flexuous, convex, 0.4 to 0.5 mm. wide, seven to eight in 5 mm. Dissepiments short, subcarinate, about half as wide as the branches. Fenestrules elliptical (especially in worn specimens), averaging about 0.6 by 0.3

mm., with from five to six occurring in 5 mm. Zoecia in three or four alternating ranges, which number is often reduced to two for a very short distance after a bifurcation. The typical number of ranges is three when the central row forms the flat median summit of the branch. In this case the number is increased to four shortly before bifurcating. Apertures small, subcircular, about one and one-half times their diameter apart longitudinally. The rows of apertures are separated by inconspicuous undulating ridges, which are at intervals elevated to form small nodes, about as numerous as the apertures. The ridges are more prominent in worn specimens. On the reverse, the dissepiments and the branches are on the same plane. The latter are finely striated.

Position and locality: Upper Coal Measures; Kansas City, Mo., Argentine, Lawrence, and Topeka, Kan. Type in author's collection.

The only species with which this is liable to be confounded is *P. nodocarinata* Ulrich. In our species, the typical number of zoecial ranges is three rather than four. The branches are somewhat flexuous and not straight. The carinate appearance is not so marked and the nodes are not so prominent. The number of branches and fenestrules in 5 mm. is another distinction between the two species. This is one of the commonest species of bryozoans in the collections studied, and is quite variable in its characters. Some of the specimens are much more closely related to *P. nodocarinata* than others.

Polypora triangularis, n. sp. Plate IV, figs. 3-3c.

Zoarium a foliar expansion of unknown size, forming a loose network. Branches strong, slightly flexuous, about seven in 1 cm.; cross-section subtriangular, resembling a sector of a circle. The width of the branches is about 0.8 mm. Obverse side only moderately convex, with subangular margins. Dissepiments rather long, of variable width, rounded, depressed, spreading slightly at each end and often faintly striated. Fenestrules large, subquadrangular, as wide as the branches, and about three times as long, averaging 2.5 mm. by 0.8 mm. Three or three and one-half occur in a space of 1 cm. Zoecia usually in five or six ranges, but just after a bifurcation there are only three or four. Apertures circular, with moderately strong peristomes, incomplete at their lower margins, like those of *Thamniscus octanarius* Ulrich. In worn specimens this feature is not apparent. Apertures small, from two to three times their diameter apart, about fourteen in 5 mm., arranged in quite regular diagonally intersecting series. Measuring diagonally, four apertures occur in 1 mm. On the reverse the branches are subcarinate, and bear a single row of prominent nodes, placed about one and one-half times their diameter apart, with from six to eight for each fenestrule.

Position and locality: Upper Coal Measures; Lawrence and Lecompton, Kan., and Kansas City, Mo. Type in author's collection.

This species is intermediate between *P. submarginata* Meek and *P. distincta* Ulrich in several respects. From the former it differs in the more elongate form of the fenestrules, the branches are subtriangular rather than subpentagonal in cross-section, the reverse side bears a row of nodes, the arrangement of the apertures is quite regular. From the latter it may be distinguished by the less elongate fenestrules and by the presence of nodes on the reverse side.

Some of the measurements agree well with those of *P. crassa* Ulrich, but the apertures of that species are closer together, the peristomes are complete, and the branches are wider.

***Thamniscus tenuiramus*, n. sp.** Plate II, figs. 5–5 *a*.

Zoarium a small frond, composed of slender branches, bifurcating at intervals of about 4 mm. Angle of bifurcation between 40 deg. and 60 deg. Branches quite convex on the obverse side, less so on the reverse side: 0.55 mm. wide and 0.45 mm. thick. Lateral margins of the branches subangular; also dentate, due to the lateral projection of the marginal ranges of zoecia apertures. No dissepiments present. Zoecia in four or five alternate ranges, these being the extremes between the bifurcations. Apertures small, circular, about twice their diameter apart, occupying the summits of transverse ridges, which increase in height toward the margins of the branches. The transverse spaces between the apertures are somewhat depressed, giving a pustulose appearance to the zoecia mouths. Eighteen apertures occur in a space of 5 mm.

Position and locality: Upper Coal Measures; Kansas City, Mo., and Lawrence, Kan. Type in author's collection.

In some respects resembles *T. divaricans* Ulrich, from the Keokuk group, but the transverse ridges of that species are more prominent and the zoarium is much more robust. *T. sevillensis* Ulrich and *T. octonarius* Ulrich, from the Coal Measures, are quite distinct.

ACANTHOCLADIIDÆ Zittel.

***Pinnatopora pyriformipora*, n. sp.** Plate II, figs. 6, 6*a*.

Zoarium a pinnate frond. Midrib slightly flexuous, 0.5 mm. wide, giving off on each side seven lateral branches in a space of 5 mm. Pinnæ rather short, two-thirds as wide as the branches, given off alternately. Obverse face with a prominent flexuous carina, bearing a row of very small nodes 0.4 mm. apart. Zoecia in two alternating rows. Apertures small, elevated, pyriform, with small end pointing towards the base of the frond, about twice their diameter apart, eighteen in 5 mm. The apertures are arranged so that one is at the

smaller angle of the junction of the pinna with the branch and two in the space between.

Position and locality: Upper Coal Measures; Argentine, Kan. Type in author's collection.

Distinguished from all other species of the genus by the form of the zoecial apertures.

***Pinnatopora ptiloporoidea*, n. sp.** Plate III, fig. 1.

Description of reverse side: Zoarium a pinnate frond. Midrib straight but slightly convex; surface apparently smooth, 0.45 mm. wide. Branches rather slender, 0.25 mm. to 0.3 mm. wide, given off alternately at an angle of about 65 deg., six in 5 mm.; total length of branches unknown, the longest measuring 4 mm., not appreciably diminishing in thickness in this distance. Branches connected by nonporiferous dissepiments. Fenestrules subquadrangular, about as wide as the branches, length varying from 1 to 2.5 mm.

The obverse side of a specimen, probably of this species, has been observed, but in such poor preservation as not to warrant a description

Position and locality: Upper Coal Measures; Lawrence, Kan. Type in author's collection.

Resembles *P. intermedia* Ulrich and *P. simulatrix* Ulrich, from the Waverly group, of Ohio, in having the lateral branches connected by dissepiments, but has the branches nearer together. From the latter it differs in having the midrib and the branches nearer equal in width. As the general appearance of the zoarium is much like that of *Pinnatopora*, it is referred to that genus.

***Pinnatopora multipora*, n. sp.** Plate III, figs. 2, 2*a*.

Zoarium a rather large pinnate frond. Midrib straight, 0.5 mm. wide, giving off on each side four branches in 5 mm. Pinnæ long and slender, about 0.3 mm. wide, given off subalternately, at an angle of about 75 deg. Zoecia in two alternating rows. Apertures small, subcircular, about their diameter apart, seventeen in 5 mm. One aperture occurs at the small angle of the pinnæ with the midrib, and five in the space between. Reverse face covered with fine longitudinal striæ and circular pores, with moderately well defined peristomes. Obverse face not seen.

Position and locality: Upper Coal Measures; Eudora, Douglas county, Kansas. Type in author's collection.

Of other species occurring in the Coal Measures, it most nearly resembles *P. trilineata* Meek, differing from it mainly in having five apertures instead of two in the space between the apertures, occurring at the junction of the pinnæ with the midrib.

Septopora interporata, n. sp. Plate III, figs. 3, 3*a*.

Zoarium a small pinnate frond. Midrib straight, rather slender, 0.6 mm. wide, with a prominent subangular median carina, bearing small nodes stationed at distances of 0.3 to 0.4 mm. apart. Lateral branches also carinate, about one-half as wide as the midrib, separated by interspaces a little more than their width apart, almost opposite on the two sides, five in 5 mm.; whole surface covered with obscure longitudinal striæ. Apertures rather large, slightly oval, separated by a space about equal to their diameter, nineteen in 5 mm. Between the apertures are situated accessory pores, which are circular, with their diameter about equal to one-third the length of the apertures. Dissepiments short, with from two to six apertures. Reverse not seen.

Position and locality: Upper Coal Measures; Argentine, Kan. Type in author's collection.

Differs from *S. pinnata* Ulrich, which it resembles, in having the lateral branches straighter and more regular. The accessory pores are much more frequent, there almost always being one between two successive apertures.

Acanthocladia pinnata, n. sp. Plate III, figs. 4, 4*a*.

Zoarium a pinnate frond; total size unknown. Primary branch 0.6 to 0.7 mm. wide, giving off on each side five branches in 5 mm. Pinnæ 0.5 mm. wide; length unknown; some are at least 5 mm. long. Obverse face, with two alternating rows of zoecia apertures on the midrib, the space between which is occupied by small nodes placed at irregular intervals. There are three or four ranges of apertures on the pinnæ. Apertures small, oval, with moderate peristomes, a little more than their diameter apart. Surface where not worn covered with small granules and fine longitudinal, undulating striæ. Reverse not seen.

Position and locality: Upper Coal Measures; Kansas City, Mo. Type in author's collection.

A. fruticosa Ulrich has oval-shaped apertures, arranged in deep furrows, and a more robust zoarium.

Rhombocladia, n. gen.

Zoaria dichotomously dividing stems, poriferous on one side only. Stems compressed, without lateral branches. Zoecial tubes very long, with thin walls. Arising near the reverse side, they are first recumbent, then curve upward and meet the poriferous surface at an angle of about 60 deg., increasing in size and the walls becoming thicker at the same time. Primitive portions of the zoecia elongate subquadrate in outline. Apertures subelliptical, with ridge-like interspaces, arranged in several alternate longitudinal ranges; also in diagonally in-

tersecting series. The reverse surface is smooth. Mesopores and hemisepta apparently absent.

The systematic position of this genus is somewhat in doubt. The obverse side of the specimens closely resembles that of some species of *Rhombopora*, but the zoecial tubes and the form of the zoarium are quite different from that genus. It is provisionally referred to the Acanthocladiidæ.

Rhombocladia delicata, n. sp. Plate I, figs. 1-1*d*.

Zoarium a long, slender compressed stem, dividing dichotomously at distant intervals. Stem subacutely elliptical in cross-section, 0.7 to 0.8 mm. wide and 0.4 mm. thick. Zoecia in about eight alternating ranges, also arranged in regularly intersecting series. Apertures subelliptical, with ridge-like interspaces, giving them the rhombic or hexagonal appearance of the apertures of *Rhombopora*. Measuring longitudinally, five apertures occur in a space of 2 mm., and four in 1 mm. measuring diagonally. Acanthopores of small size present at the cell angles. Reverse side smooth. The primitive portions of the zoecia are usually visible from this side. The specimens usually adhere to the matrix on the obverse side.

Position and locality: Upper Coal Measures; Eudora and Lawrence, Kan., and Kansas City, Mo. Type in author's collection.

Occurs in the Iola limestone* (No. 98, Broadhead's Gen. Sect. of the Coal Measure rocks of Missouri) at Kansas City, Mo., associated with the following species: *Cystodictya inequimarginata*, n. sp., antea; *C. divisa*, n. sp., antea; *Fenestella limbata* Foerste; *F. remota* Foerste; *F. shumardi* Prout; *F. ovatipora*, n. sp., antea; *Polypora submarginata* Meek; *Thaminiscus tenuiramus*, n. sp., antea; and *Chainodictyon laxum* Foerste.

UNIVERSITY OF KANSAS, Lawrence, January, 1900.

* Haworth and Kirk, this journal, vol. II, p. 109.

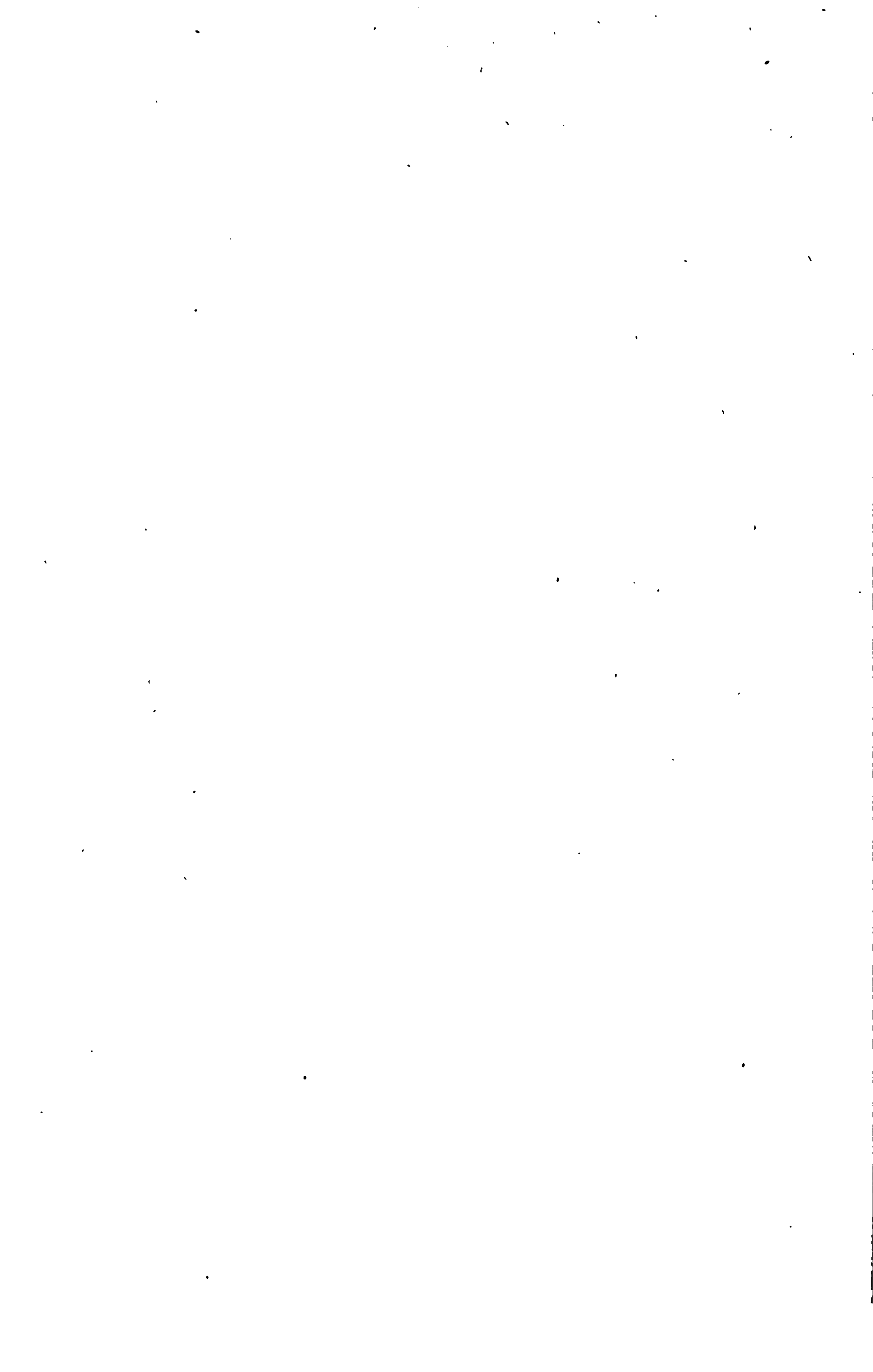


PLATE I.

*Fig. 1.—*Rhombocladia delicata* Rogers.

1. A specimen, natural size.
1*a*. Cross-section of same, × 5.
1*b*. Horizontal section, × 27.
1*c*. Vertical section, × 50. (This figure is upside down. It is an oblique section, so that openings of the zoecial tubes are not shown.)
1*d*. Portion of reverse surface, × 27.

Fig. 2.—*Cystodictya inequimarginata* Rogers.

2. Specimen, natural size.
2*a*. Transverse section of same, × 5.
2*b*. Portion of surface, × 27.

Fig. 3.—*Streblotrypa ulrichi* Rogers.

3. A specimen, natural size.
3*a*. Portion of stem, × 27.

Fig. 4.—*Fenestella hexagonalis* Rogers.

4. Obverse side, × 27. (The nodes are hardly prominent enough.)
4*a*. Reverse side, × 27. (The nodes should cover all the elevated part of the drawing.)

Fig. 5.—*Fenestella dentata* Rogers.

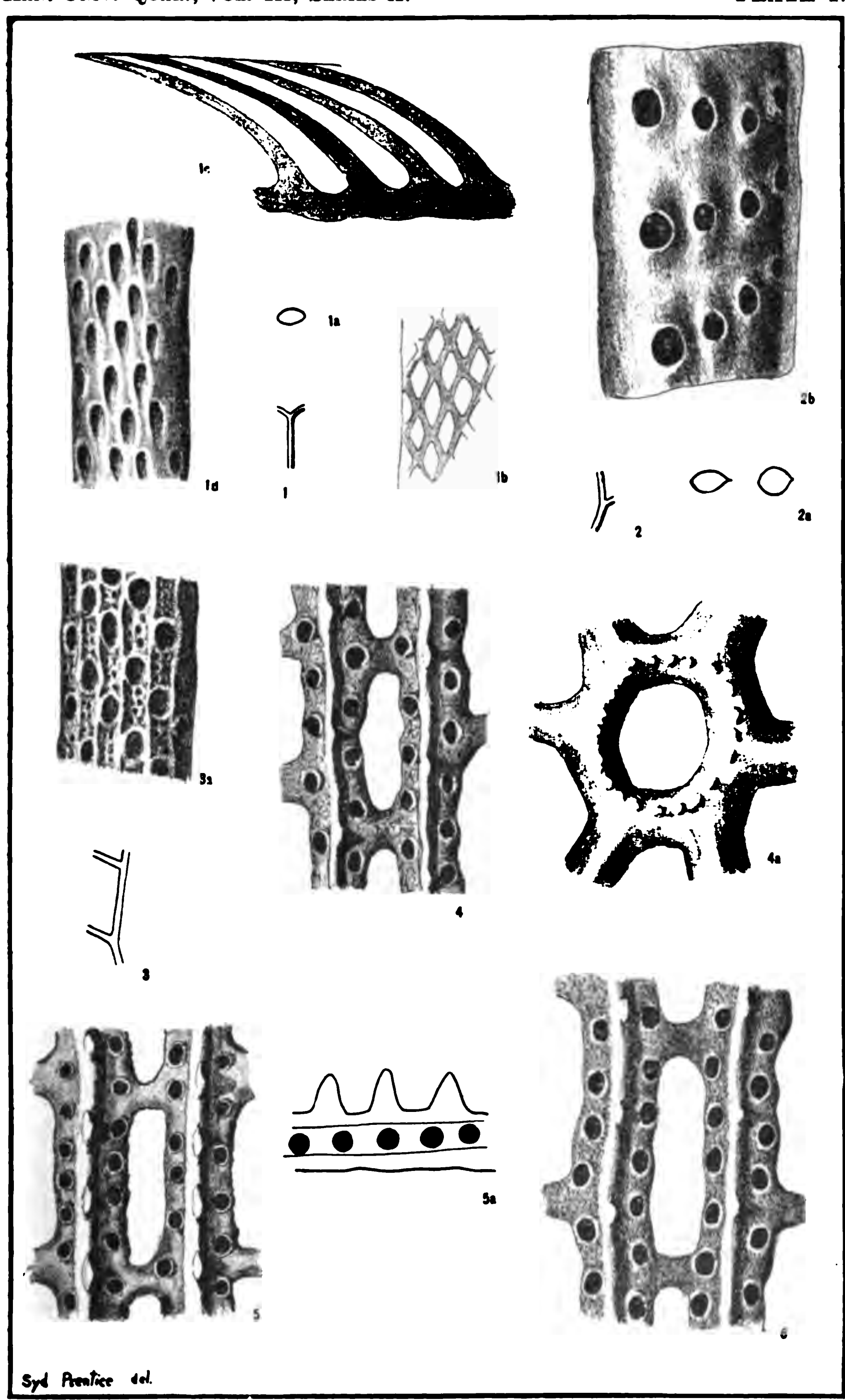
5. Obverse side, × 27.
5*a*. Profile view of a branch, to show dentate appearance of carina, × 27.

Fig. 6.—*Fenestella kansasensis* Rogers.

6. Obverse side, × 27.

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*When these figures were made, the obverse side of the species had not been seen; consequently no drawings of it appear.



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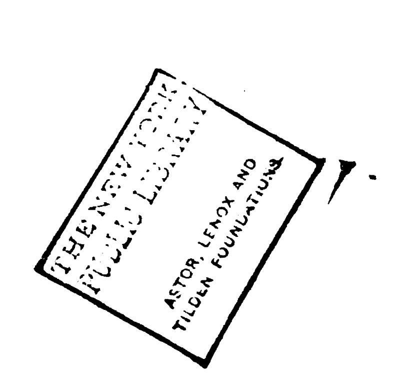




PLATE II.

Fig. 1.—*Fenestella ovatipora* Rogers.

1. Obverse, $\times 27$.

Fig. 2.—*Fenestella missouriensis* Rogers.

2. Obverse, $\times 27$.

Fig. 3.—*Polypora aspera* Rogers.

3. Portion of zoarium, $\times 6$.

3*a*. Obverse face of portion of branch, $\times 27$.

Fig. 4.—*Polypora flexuosa* Rogers.

4. Obverse, $\times 27$.

Fig. 5.—*Thamniscus tenuiramus* Rogers.

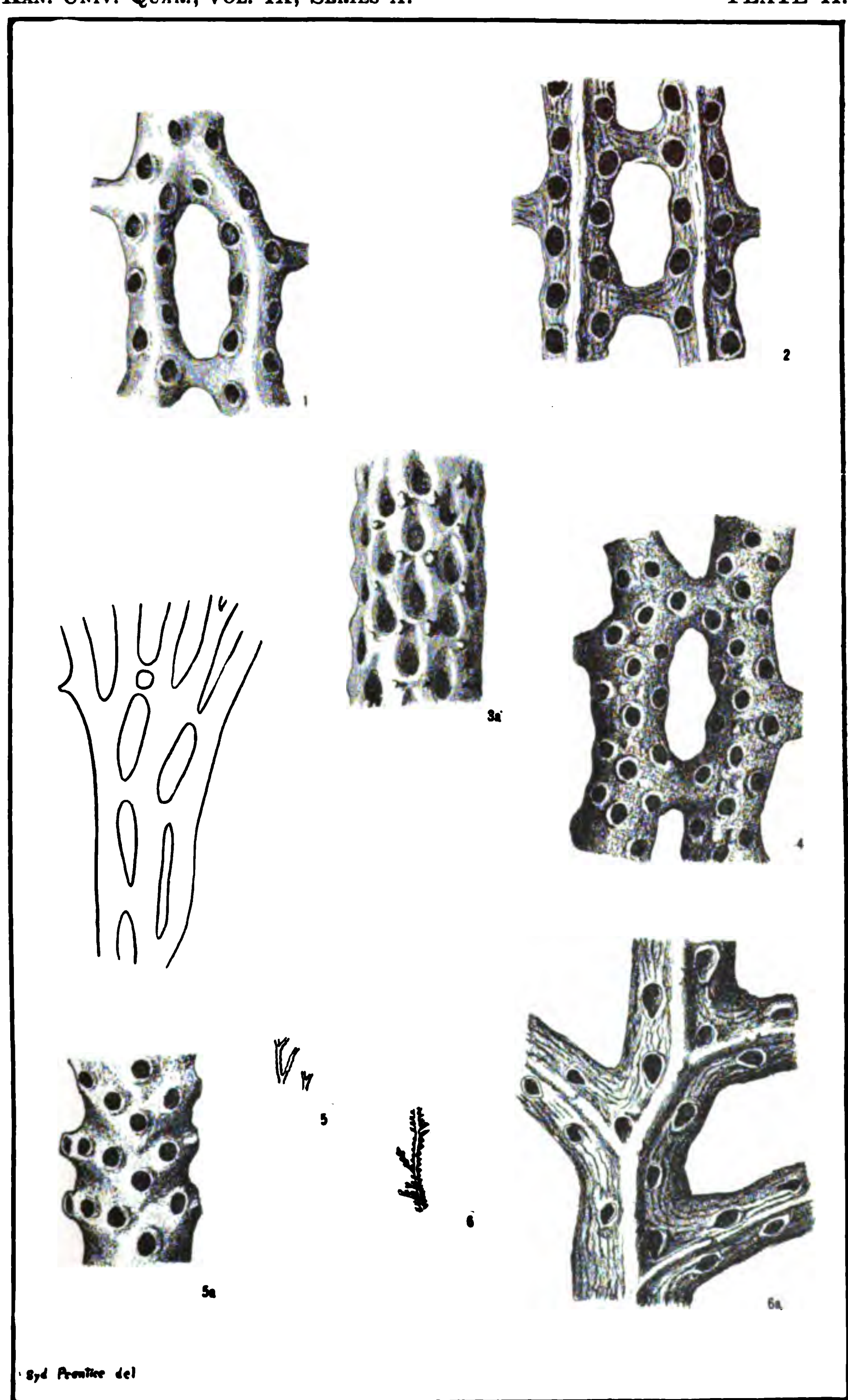
5. Specimen, natural size.

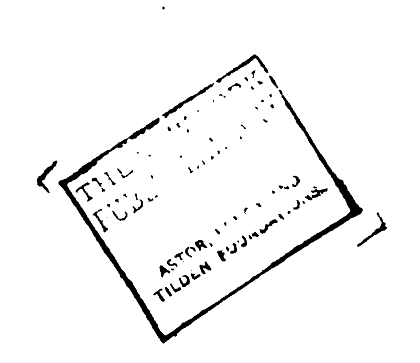
5*a*. Obverse face, $\times 27$.

Fig. 6.—*Pinnatopora pyriformopora* Rogers.

6. Specimen, natural size.

6*a*. Obverse face, $\times 27$.


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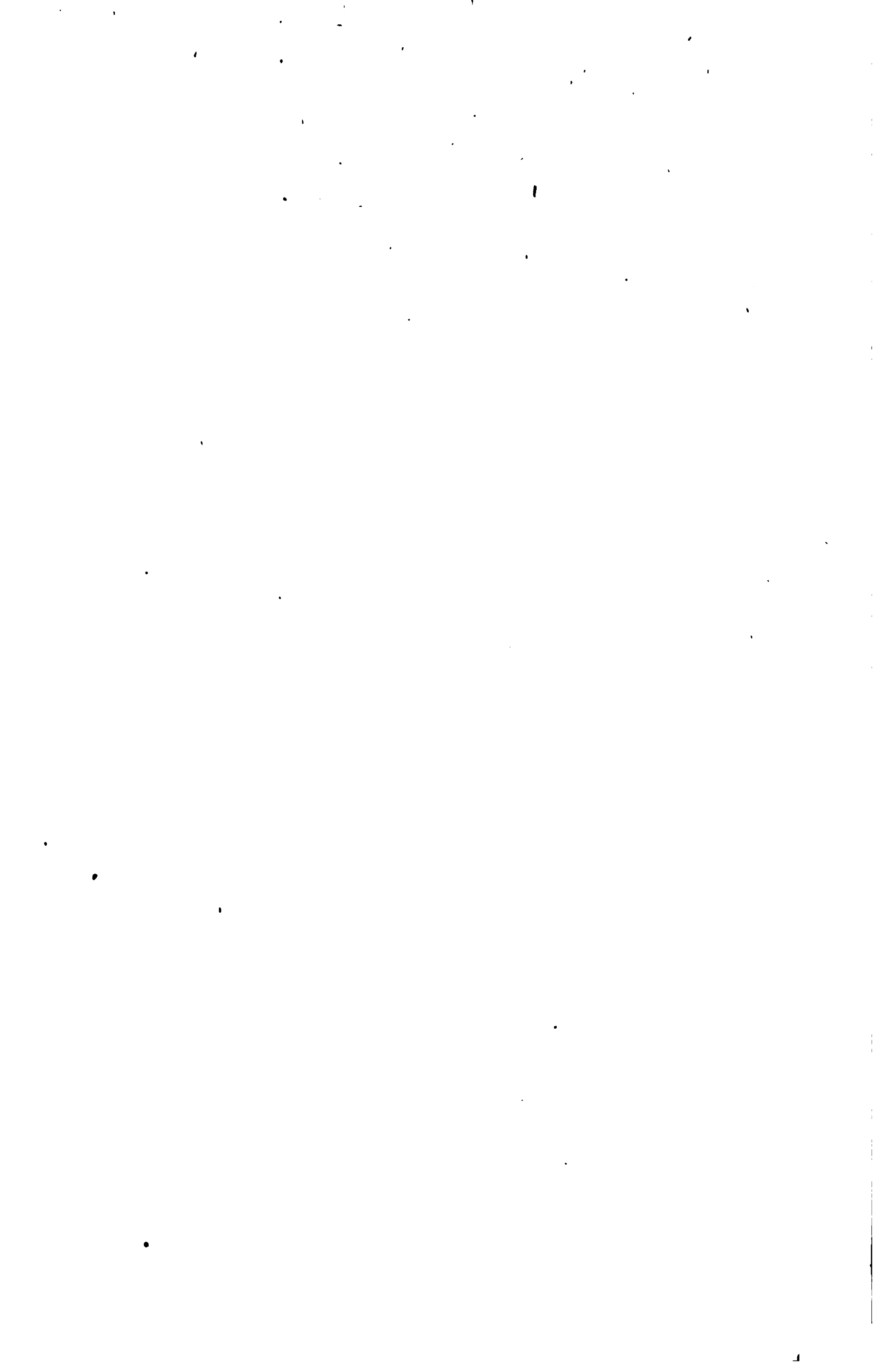


PLATE III.

Fig. 1.—*Pinnatopora ptiloporoidea* Rogers.

1. Reverse, × 10.

Fig. 2.—*Pinnatopora multipora* Rogers.

2. Specimen, natural size.
2*a*. Horizontal section, × 27.

Fig. 3.—*Septopora interporata* Rogers.

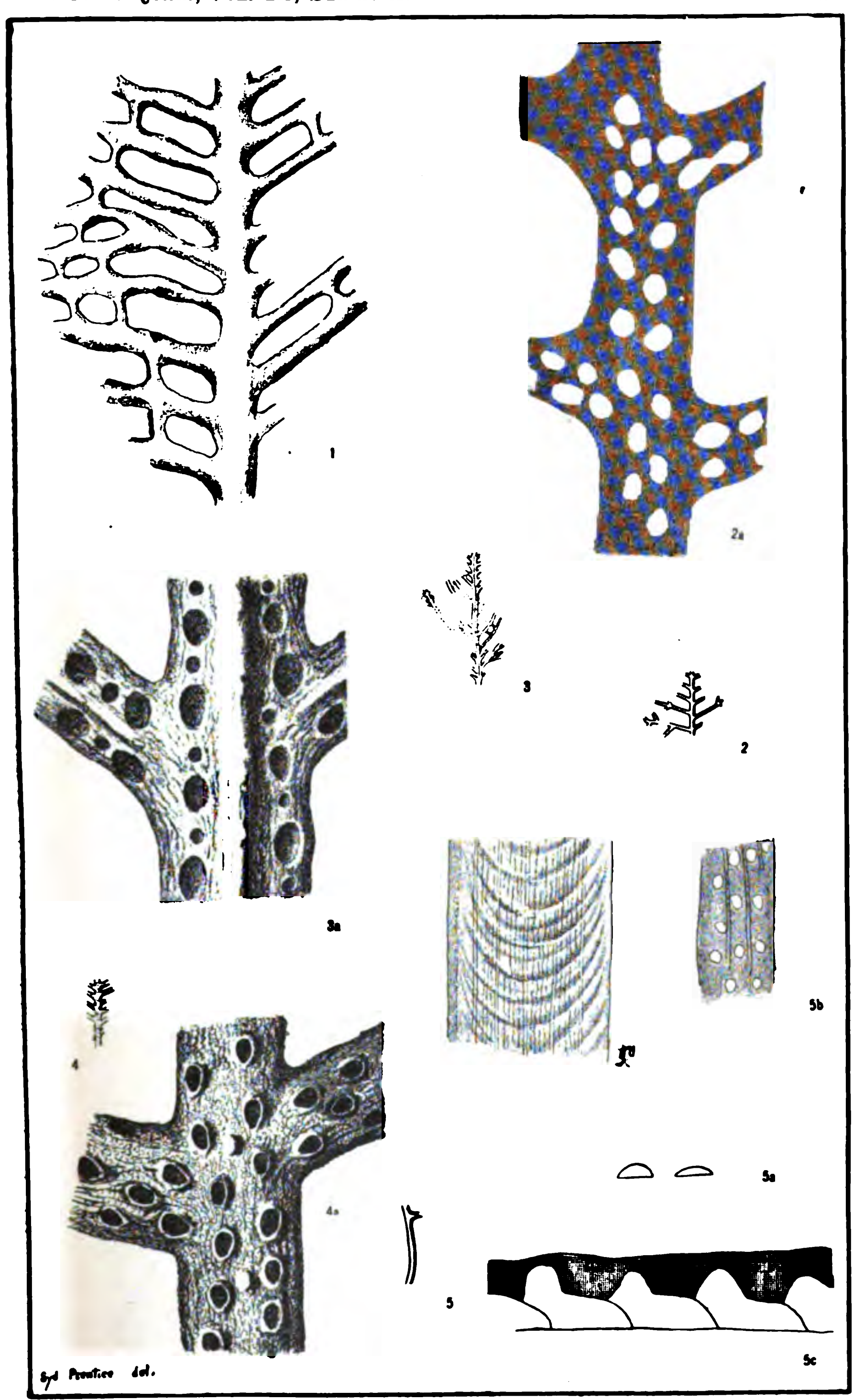
3. Specimen, natural size.
3*a*. Obverse, × 27. (The apertures are a little too far apart.)

Fig. 4.—*Acanthocladia pinnata* Rogers.

4. Specimen, natural size.
4*a*. Obverse, × 27.

Fig. 5.—*Cystodictya divisa* Rogers.

5. Specimen, natural size.
5*a*. Transverse section of several hemibranches, × 5.
5*b*. Horizontal section, × 10.
5*c*. Vertical section, × 27.
5*d*. Non-poriferous surface of a hemibranch, × 27.


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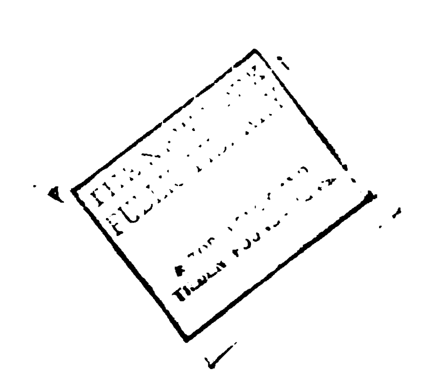




PLATE IV.*

Fig. 1.—*Streblotrypa striatopora* Rogers.

1. Surface of a branch, ×20. (The arrangement of the apertures is a little too regular.)

Fig. 2.—*Polypora elliptica* Rogers.

2. Portion of obverse, ×27.

Fig. 3.—*Polypora triangularis* Rogers.

3. Obverse surface of a branch, ×27. (Diagonal arrangement of the apertures is not so marked.)

3*a*. Portion of the zoarium, ×7.

3*b*. Part of the reverse, ×6.

3*c*. Cross-section of branch, enlarged.

Fig. 4.—*Stenopora spissa* Rogers.

4. Zoarium, natural size.

4*a*. Surface, ×27.

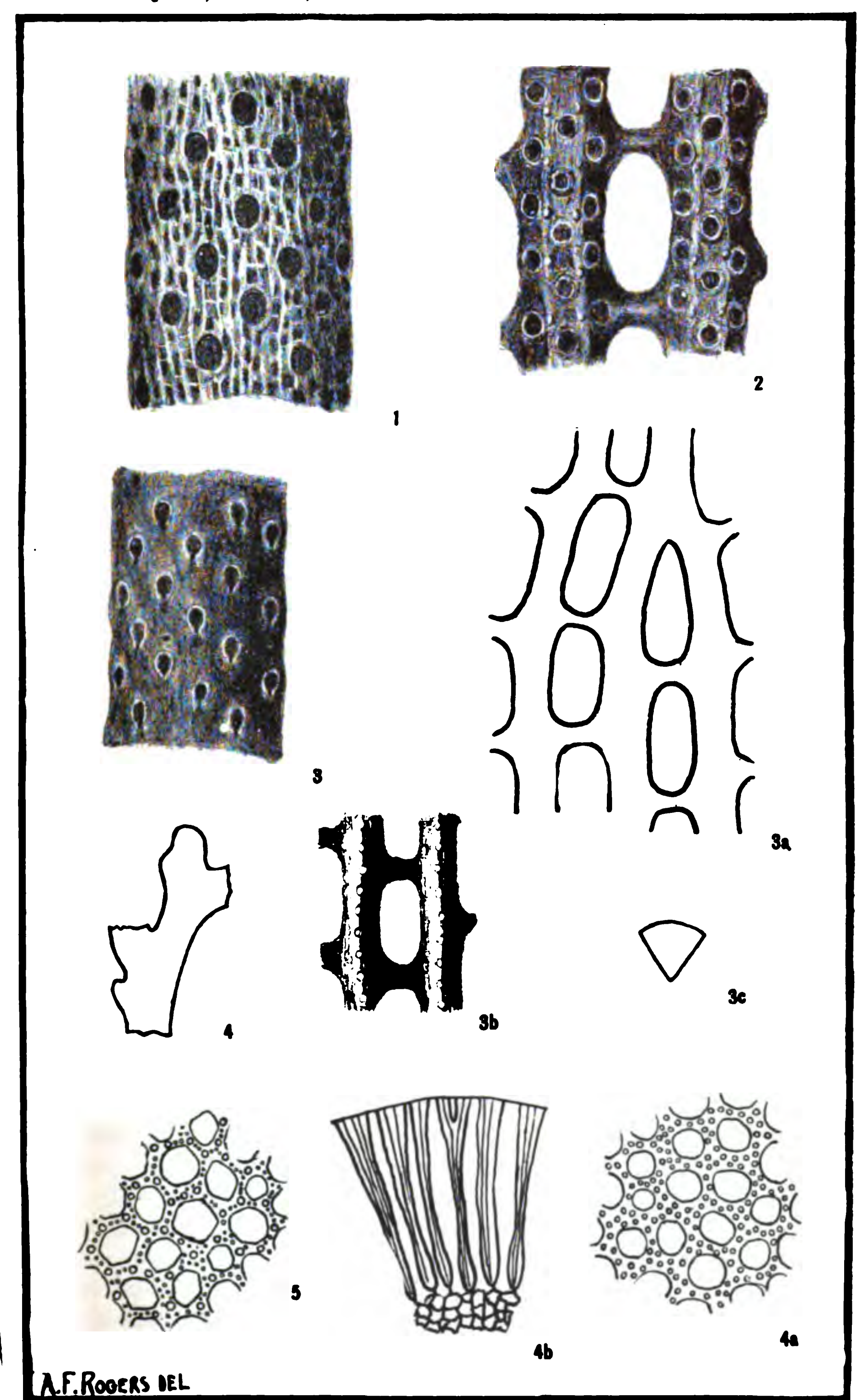
4*b*. Cross-section of branch, ×13, showing the thickened zoecial walls.

Fig. 5.—*Stenopora spinulosa* Rogers.

5. Surface, ×27.

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*The drawings of this plate are semi-diagrammatic.


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A.F. ROGERS DEL

TWO NEW CRINOIDS FROM THE KANSAS CARBONIFEROUS.

Contribution from the Paleontological Laboratory No 53.

BY J. W. BEEDE.

With Plate V.

Scaphiocrinus? washburni, n. sp. Plate V, figs. 2, 2*a*.

CALYX broadly obconical, somewhat wider than high, rather stout, and smooth. Infrabasals rather large, bent upward at outer end, exterior outline pentagonal, plainly visible in the side view of the calyx, well defined. Column large, circular, composed of alternately thick and thin pieces, the outer half of the sutures radially milled, the median canal of moderate size. Basals large, three hexagonal, and the posterior and right posterior ones heptagonal for the reception of the anals; the plates are nearly all equal, and the sutures are placed in a shallow, rounded furrow, which in branching at the angles of the plates gives them a rounded appearance, so that the plates appear subsemicircular in outline. The radials are the largest plates of the calyx, all pentagonal, all about equal, save the right posterior, which is smaller than the rest; the entire surface truncated above, edge slightly beveled, wider than high, entire upper surface faceted; the transverse ridge is milled, the lateral corners of the plates drawn in, apparently leaving a pore which connected with the body cavity of the calyx; there is a dorsal canal piercing the upper surface of the plates; the inner edges of the plates are drawn in at the center and extend in the form of a ridge to the canal. Costals 1 x 5, about half the size of the radials, pentagonal, line of articulation with the radial gaping, lateral edges constricted and apparently not in contact, about twice as wide as high. The first interradial is large and situated well down in the cup, supported by the posterior basal and the one at its right, on the sides by the special anal and the right posterior radial, and supports another anal above it on its truncated top. The special anal is moderately large and hexagonal, bounded on the right by the two interradials, below by the truncated upper surface of the posterior basal, on the left by the left posterior radial and the space between it and the costal; it is about half within the calyx. Above the first interradial is a second, somewhat smaller, pentagonal plate which is about, or a little less than, half within the calyx. This

plate, together with the special anal, supports the posterior portion of the ventral sac (apparently two columns of plates), which seems to be composed of rather stout five- to seven-sided plates, with no, or very small, pores at the angles; they have a botrioidal surface. At one side and on the top of the sac there seems to be a madreporite plate pierced by good-sized pores. The sac was apparently about the size of the calyx, or perhaps the calyx and costals together. Arm plates rounded on the exterior, not at all, or very slightly, wedge-shaped at the base, and moderately stout. Pinnulæ present and of moderately good size.

Measurements.	Height.	Width.	
Column	——	8 mm.	
Infrabasals	3 mm.	5 "	
Basals	10 "	11 "	
Radials	8 "	14 "	(right posterior smaller).
First interradial	8 "	9½ "	
Second interradial	5 "	6 "	
Special anal	8 "	8 "	
Costal	6 "	11 "	
Calyx	17 "	28 "	

Position and locality: Upper Coal Measures; Topeka, Kan., from the horizon of the Osage coal. Now in the collection of Washburn College, in honor of which it is named.

The species seems to belong to the *Poteriocrinoidea*, though there is some difficulty in locating it generically, as it seems to combine some of the characters of several genera. It agrees with *Homocrinus* in having a round dorsal canal piercing the first radials, but differs from it in that it has pinnules, a robust calyx, and the entire top of the radials truncated. According to the definition of *Poteriocrinus*, the presence of the round dorsal canal in the radials removes it from that genus, as would also the fact that the facets of the radials face upwards rather than outwards. It differs from *Scaphiocrinus* in having a circular column, and the fact that the transverse ridge does not occupy nearly the whole of the upper surface of the radials and the brachials are not long. However, it agrees in other respects with this genus better than any other, and it is provisionally referred to it.

Zeacrinus? robustus, n. sp. Plate V, figs. 1, 1*a*.

Calyx shallow, saucer-shaped or nearly flat, unsymmetrical, five or six times as broad as high, deeply concave at the base; plates tumid, and the sutures are in depressions; surface finely granular. Infrabasals five, equal, half concealed by the column, deeply concave and superior to the basals, forming a large elevation in the interior of the cup, nearly one-fourth its entire width and fully one-half its height; column round, composed of thin plates, which are carinated, and the

sutures are crenulated; the canal is round and small. Basals five, large, tumid, three hexagonal and two heptagonal, unequal, situated below the infrabasals and forming a large part of the real body cavity of the cup. The three anterior basals are equal, about as broad as high, very convex, the posterior one compressed laterally, superior lateral edges longer than the others; truncated side for the support of interradial short, side next the radianal long; the right posterior basal heptagonal very broad, left posterior side very long, side adjacent for the reception of the radianal very short, the latter being situated between the posterior basal and the right posterior radial. Radials five, large, very moderately ascending, placed superior to the basals, five- to seven-sided, quite massive, more than twice as large as the basals, convex, twice as wide as high, upper exterior portion much beveled and concave; plates separated at the corners and often along the line of union; at the upper union there seems to be an opening that communicates with the calyx cavity between the arms; right and left posterior radials forced apart fully one-half the diameter of either by the interradial and radianal; the upper surface is faceted the entire width of the plate, two external ridges present and milled; the remainder of the surface is nearly flat or a little concave; the plane of these surfaces is not horizontal but the inner side of each is higher than the outside, so that if each were produced inward they would form rather an obtuse cone; the inner notch occupies about a third of the upper surface of the plate. Radianal long, coffin-shaped, curving upward above, about twice as long as wide, pentagonal, side adjacent to the right radial much the longer; the superior side supports an anal which is hexagonal, very thick, six-faceted above, touching right radial for a short distance, one and one-half times as high as wide, widest above, mostly without the calyx. Anal large, heptagonal, very thick, one-third within the calyx, broadest above; height one and one-half times the width.

A portion of the vault of this specimen remains, somewhat crushed down into the calyx. It appears to have been in the form of a pyramid, about as broad as high, composed of rather heavy plates, which were rather rough. It appears to have been rather angular, though it may have been conical. Several rather irregular plates are preserved, three of which seem to be from around the aperture; they are rather massive, five- or six-sided, nearly smooth on the exterior; articular surfaces are deeply faceted and roughened, while the articular surfaces of the other plates of the sac are milled.

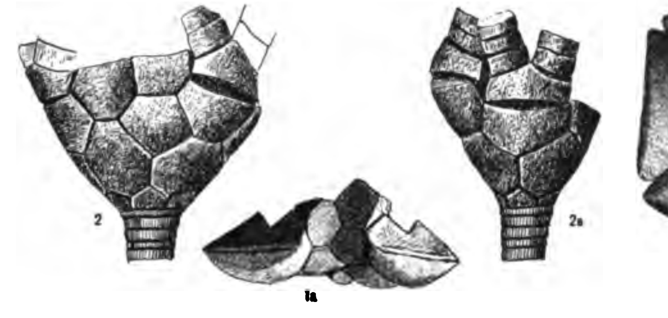
Measurements.	Height.	Width.
Column segments	1 to 1½ mm.	4½ mm.
Infrabasals	4 "	3 "
Three anterior basals	8 "	9 "

Measurements.	Height.	Width.
Right posterior basal	9½ mm.	11 mm.
Posterior basal	9 "	7½ "
Radial	9 "	19 "
Radianal	8½ "	4½ "
Interradial	7½ "	5½ "
Anal	8 "	4½ "
Calyx	7 "	36 "

Position and locality: The specimen is labeled, "From the Upper Coal Measures; Kansas City." University of Kansas Museum.

It is impossible to locate the specimen generically with any degree of certainty without more of the specimen preserved. The ventral sac seems to have been angular and the stem round. For this reason it is left with *Zeacrinus*. The upper extremities of the radials do not meet, but leave a small aperture, which seems to communicate in life with the general body cavity. I know of no Coal Measures crinoid with which it is likely to be confounded.

JANUARY, 1900.





DESCRIPTION.

Zeacrinus ? robustus Beede.
Fig. 1.—Dorsal aspect of the calyx.
Fig. 1*a*.—View of azygous side of the calyx.

Scaphiocrinus ? washburni Beede.
Fig. 2.—View of azygous side of the calyx.
Fig. 2*a*.—Side view of the calyx, which is somewhat compressed.

SOME FISH TEETH FROM THE KANSAS CRETACEOUS.

Contribution from the Paleontological Laboratory No. 54.

BY S. W. WILLISTON.

With Plates VI to XIV, inclusive.

THE following notes and descriptions of various pycnodont and selachian teeth from the Kansas Cretaceous are the result of an endeavor to determine the material in the University Museum which has accumulated in the last ten years, supplemented by a collection kindly loaned me for study by Mr. T. W. Stanton, of the National Museum. The material is by no means exhaustive, nor even sufficient to settle several doubtful points, but I trust that, incomplete as it is, it will be of service for a more thorough study in the future. As a means to this end I have figured fully nearly everything that has been examined.

"The specific determination of the detached teeth of sharks and skates is little more than guesswork, and to decide upon their generic relationships with any approach to certainty is also often very difficult." *

Nevertheless, because such detached teeth are so often found, and connected series so very rarely, an attempt at their determination is desirable. Fortunately, in the present collection there are several forms represented by such complete specimens, that the positive addition they afford to the knowledge of the species and genera is very welcome.

PYCNODONTIDÆ.

The pycnodonts are a peculiar group of ganoid fishes, whose remains have been found in the Jurassic, Cretaceous and Eocene deposits of Europe, North America, Asia, and Australia. They are all rather small fishes, very much flattened and oval in shape, covered with rhomboidal scutes having close-lying spines, which give a ribbed appearance. The united palatine and vomer of the upper jaws are provided with five rows of round or oval, smooth-pavement teeth; the premaxillary with two or four chisel-like teeth. The dentaries below have a like number of teeth, similar to those of the premaxillary,

* Woodward: Proc. Geol. Assn., XIII, 190.

while on the splenial there are three, four or five rows of pavement teeth similar to those of the vomer.

Cœlodus brownii. Plate VI, fig. 12.

Cœlodus brownii Cope, Journ. Acad. Nat. Sci. Phil. IX, 447, pl. XX, f. 19.

A fragment of the left lower jaw, containing two rows of teeth, the middle and the inner. There are four crowns preserved on the inner row, nearly corresponding in length with the six teeth of the middle row, of which only two have the crowns preserved. Cope's type had only the middle and external rows, and none of the teeth had well-preserved crowns. The middle teeth seem to correspond exactly in size with the types.

On the inner side the jaw projects as a rather broad trough, with a thin edge, apparently broader posteriorly than anteriorly. Its width here is nearly as great as the width of the inner row of teeth. The inner teeth are large, their width equal to nearly half their length. The surface of the crowns is smooth and convex, more so antero-posteriorly than transversely. The middle row has the teeth placed a little obliquely to the others, and the surface is more flattened transversely in the middle. The axes of the crowns of the two rows are placed at a distinct angle with each other.

Length of four teeth, inner row	36 mm.
Transverse diameter of crowns, inner row	17 "
Length of five teeth, middle row	31 "
Transverse diameter of crowns, middle row	12 "
Thickness of jaw, at middle row of teeth	22 "

The specimen was collected from the Kiowa shales near Belvidere, by Mr. C. N. Gould.

Cœlodus stantoni, n. sp. Plate VI, fig. 12; plate VIII, fig. 6.

A fragment of the right lower jaw, containing two perfect crowns of the internal row, together with the bases of four teeth of the middle row, evidently represents a species distinct from the previous one. The teeth are much smaller in size, more elongated and distinctly kidney-shaped, the ends narrowed. The surface is smooth, strongly convex antero-posteriorly, and gently so from side to side. The jaw is much less robust than in the preceding species.

Transverse diameter of tooth, internal row	14 mm.
Antero-posterior diameter of same	5½ "
Length of four teeth, middle row	17 "
Transverse diameter of tooth, middle row	11 "

The middle teeth seem to be larger in proportion to those of the internal series than in the preceding species. Kiowa shales.

—

Mesodon abrasus.

Mesodon abrasus Cragin, Colorado College Studies, V, 1894.

"This name is proposed for certain pycnodont teeth of low, rhomboidal form and feebly convex upper surface which occur in No. 3 of the Belvidere section, southwest of the Belvidere railroad station, and seem to agree with the large mandibular teeth of *Mesodon.* The specific name refers to the occurrence in the type species of two small, oblique facets produced at one end by attrition. The type has a height (above root) of 3 mm., a length of 13 mm., and a breadth of 5 mm."

"To the vomerine set of the same species may belong the rotund, oval or nearly hemispherical teeth of similar height but smaller size, which occur not uncommonly at the same locality and horizon, the largest now available example of which measures about 6 and 7 mm. in major and minor horizontal diameters."

In the National Museum collection there are several teeth, occurring singly, corresponding to the vomerine teeth described by Cragin. That they belong with the other teeth there described is very doubtful—indeed it is doubtful whether the other teeth belong with *Mesodon*, since it is impossible to locate the genus from single teeth. It is not at all impossible that the vomerine teeth are identical with Cope's *M. diastematicus.* The larger teeth may be the same as those of either the above-described species of *Cœlodus.*

The largest of the specimens in the present collection measures 10 by 7½ mm.; several smaller examples have diameters of 6 and 5 mm. (See plate XII, fig. 4.)

LEPIDOSTEIDÆ.

Lepidotus, sp.

In the National Museum collection there is a single example of a scute pertaining to some lepidotid fish (No. 1063, Kiowa shales). Cope has described *Macrepistius* of this family from a stratum between the Upper and Lower Trinity Sands of Texas. It seems very probable that the teeth referred to the vomer of *Mesodon abrasus* really belong here.

MYLIOBATIDÆ.

Ptychodus agassiz.

Teeth with the crown more or less elevated and overhanging, ornamented with transverse or radiating ridges, and surrounded by a larger or smaller, finely marked marginal area. Surface of the root smooth.

This genus of Upper Cretaceous selachians was for a long time placed among the cestracionts, but recent discoveries of the nearly complete dentition render it more probable that the proper location is with the Myliobatidæ. The living Myliobatidæ, or sea-devils, are

broad, flat fishes, allied to the rays, with a disk-like body. Many attain an enormous size, fifteen or twenty feet in length, and weigh a thousand pounds or more. In some the pectoral fins take on almost the character of limbs, and are said to be used in scooping up their food and transferring it to the mouth. The teeth are flat and pavement-like, and are used for crushing crabs and shell-fish. They are viviparous, and for the most part live in tropical or semitropical waters.

The teeth in *Ptychodus* are not less than 500 in number in each jaw, at least in some species. They are arranged in parallel rows, decreasing in size from within outward, except that in the supposedly upper jaws the median row is composed of small, low and smooth teeth, very much unlike the immediately adjacent ones. In *P. mortoni* there are eight rows on either side of this median row, or seventeen in all. The lateral teeth become more transversely elongated, the surface markings less conspicuous, and the form more unsymmetrical. About fifteen species of the genus have so far been discovered, all from the Upper Cretaceous. One or two species, including our most common one, have been discovered in both Europe and North America, and it is not improbable that the identity of yet others will be established when they are better known. The teeth vary so much in size and shape in the same individual that the identification from single specimens is often impossible or a matter of great uncertainty.

Ptychodus mortoni. Plate VII; plate VIII, fig. 1; plate IX.

Ptychodus mortoni (Mantell) Morton, Journ. Acad. Nat. Sci. Phil. VIII, 215, pl. X, f. 7; Agassiz, Poiss. Foss. III, 158, pl. XXV, ff. 1-3; Leidy, Proc. Acad. Nat. Sci. Phil. 1868, 205; Ext. Vert. Fauna, 295, pl. XVIII, ff. 1-14: Cope, Cret. Vert. 294; Woodward, Quart. Journ. Geol. Soc. XLIII, 130; Cat. Foss. Fishes Brit. Mus. I, 159; Proc. Geol. Assoc. XIII, 191, pl. V, f. 4—Alabama, Mississippi, Niobrara of Kansas, English Chalk.

This species is the most common one of this genus in the Kansas Cretaceous, occurring only in the Niobrara beds, so far as I am aware, and, for the most part at least, in the lower part of the beds. I have before me at the present time two excellent series of teeth of this species; one, including about eighty teeth, obtained from the estate of the late Joseph Savage; the other collected in the vicinity of Castle Rock, in Trego county, by Prof. E. S. Rose—an exceedingly interesting specimen, because most of the teeth are in place in the matrix. A number of the teeth of the Savage specimen have been arranged serially and photographed in plate VII. Of course the arrangement is not the natural one, but the plate will show in an excellent way many of the characters of the teeth better than they can be described. In plates VIII and IX are given three views of portions of the Rose specimen; that of plate VIII (fig. 1) shows a little more than one-half of the upper view. One end (the left of the figure) has

been folded underneath obliquely. This folded end is shown in plate IX, fig. 1. Figure 2 of the same plate gives a view of a transverse series, as arranged from the loose teeth taken from the right end of the specimen — the one that protruded from the chalk when discovered. About 480 teeth, all told, were obtained, and doubtless not a few had been lost before the specimen was discovered. The set is referred to the upper jaw, on the supposition of Woodward that the small median teeth belong in this jaw.

Not a trace of osseous substance is preserved in the specimen. The cartilage of the sharks' jaws is often preserved in a soft, calcified condition, but it is evident that the material in which the teeth of *Ptychodus* were lodged was of a more perishable nature, accounting doubtless for the fact that *Ptychodus* teeth are so rarely found associated.

The teeth of this species differ markedly from those of all other known species in having the center of the crown raised into a conical apex, the summit of which is crossed by a short transverse ridge from which other diverging ridges run. In the smaller lateral teeth these ridges become less well marked and occupy a relatively smaller space, becoming almost obsolete in the fifth row. The marginal area is formed of fine reticulations in many of the larger teeth, though in most of these and in all the smaller teeth the markings are more like a fine punctulation, clearly visible only with the aid of a lens, giving a uniform, finely roughened appearance. The median upper row is composed of low, flattened teeth, transversely oval or subquadrate in shape, with a slight elevation in the middle, and finely roughened throughout the whole coronal surface, there being only the slightest trace of the divergent ridges on the summit of the elevation. This does not quite agree with Woodward's description of these teeth, in which he states that they are "not marked with the radiating ridges, but exhibit a minute smooth eminence in the middle of the crown." Possibly this effect is due to wear.

Ptychodus polygyrus. Plate XI, fig. 9; plate X, fig. 14.

Ptychodus polygyrus (Buckland) Agassiz, Poiss. Foss. III, 156, pl. XXV, ff. 4-11, pl. XXV*b*, ff. 21-23; Gibbes, Journ. Acad. Nat. Sci. Phil. I, 299, pl. II, ff. 5, 6; Leidy, Proc. Acad. Nat. Sci. Phil. 1868, p. 208; Cope, Cret. Vert. 294; Woodward, Cat. Foss. Fishes Brit. Mus. I, 143, pl. V, f. 7—Senonian, Turonian of Europe, Rotten Limestone of Alabama, Niobrara of Kansas.

? *Ptychodus latissimus* Agassiz, l. c., fig. 8; Dixon, Foss. Sussex, pl. XXX, ff. 1, 2.

A single tooth of very large size from the lower beds of the Niobrara Cretaceous of the Smoky Hill river is referred to this species provisionally. Until numerous specimens are examined there can be no certainty of its correct location, though the resemblances are suffi-

ciently great to render the determination not improbable; at least with some of its varieties.

***Ptychodus martini*, n. sp. Plate X.**

A large series of teeth, 110 in number, found together in the Niobrara chalk of the Smoky Hill river, and collected by Mr. H. T. Martin, cannot be indentified with any described species. I have photographed them, arranged as symmetrically as possible, but with no assurance that the arrangement is a natural one. In fact, it is not improbable that the teeth belong to both upper and lower jaws. The teeth apparently from the lower median row are much elongate transversely, with a very flat crown, wherein they differ from the teeth of other known species. The ridges are nine or ten in number, and reach nearly to the lateral margin. In some of the teeth several of the ridges form loops near the extremities. The marginal area of granulations is small, and presents scarcely any distinct vermiculations. The teeth of the lateral rows are less elongated than those of the middle one, though still more so than is usual. The granulations become rather more extensive in area proportionally in the small teeth, as is the case with other species. A series (left vertical row of the plate) that may belong in the medio-lateral rows of the upper jaws are more nearly square in shape, and the crown has a distinct, though low, convexity extending over nearly its whole area. Antero-posteriorly the surface is nearly flat, with a moderate convexity of the margin. The surface posterior to the large grooves on the upper part shows small, radiating and branched ridges.

The largest teeth measure 45 by 20 mm.; the ones more nearly square, 35 by 25 mm.

***Ptychodus anonymus*, n. sp. Plate XI, figs. 5-8, 16-18, 20-22, 24.**

Seven teeth of nearly uniform size, four of them united in the matrix, from Walnut creek, Kansas, seem to belong to a species distinct from any previously described (figs. 16-18). They are of about the same size as those described as *P. whippleyi* and *P. occidentalis*, but will be distinguished from the former by the more broadly conical crowns. In the teeth of this size of *P. whippleyi* the crown is much compressed, standing up, tooth-like; in the present specimens they are nearly straight or gently concave from the apex to the rims. From *P. occidentalis* the species will be distinguished by the very distinctly reticulate marginal areas, the transverse ridges not reaching to the rims of the crown. Other specimens agreeing in these characters are from the Niobrara. The horizon is probably Benton.

Ptychodus occidentalis. Plate XI, fig. 4; plate XII, fig. 13.

Ptychodus occidentalis Leidy, Proc. Acad. Nat. Sci. Phil. 1868, p. 207; Ext. Vert. Fauna West. Terr. 308, pl. XVII, ff. 7, 8, XVIII, ff. 15-18; Cope, Cret. Vert. 244—Niobrara, Benton of Kansas.

Two teeth, one from the same conglomerate that yielded the teeth referred to *P. janewayii*, the other, without locality, from Mr. Joseph Savage's collection, I refer to this species. The species differs from the following in having the transverse ridges continued to the lateral rims, and not separated by an area of fine reticulation. The anterior surface has finer, elongated, nearly straight ridges and grooves in this species, while in the others the markings are reticulate or vermiculate.

Ptychodus janewayii. Plate XII, figs. 9, 10, 11.

Sporetodus janewayii Cope, Hayden's Bull. U. S. Geol. Surv. No. 2, 1874. pl. XLVII.

Ptychodus janewayii Cope, Cret. Vert. 244.

"Surface irregularly convex, covered with a dense layer, which does not exhibit pores, and is thrown into transverse or oblique ridges. Surface with four folds, which traverse it obliquely from border to border. At the base of the outer, at one end, is a series of adherent tubercles; at the basis of that, at the opposite end, is a broken fold, with tubercles at its outer base. Length 0.0045 m., width 0.0025 m. A portion of a larger and more central tooth has the surface with an unsymmetrical convexity, and is crossed transversely by five folds, from border to border." Cope, l. c.

Three small teeth, shown enlarged in pl. XII, ff. 9-11, from the conglomerate containing specimens of *Corax curvatus*, appear to belong to this species. The horizon of the conglomerate is near the line of contact between the Dakota and Benton, in Ellsworth county. Cope's type was from a bed of conglomerate containing *Lamna* and *Oxyrhina* teeth of small size near Stockton. It is probable that the horizon is the same in both.

Ptychodus whippleyi. Plate XI, figs. 10-15.

Ptychodus whippleyi Marcou, Geol. North Amer. HH. 33, pl. IX, f. 4; Leidy, Extinct Vert. Fauna, 300, pl. XVIII, ff. 19, 20; J. S. Newberry, Rep. Expl. Exp. 147, pl. III, f. 2; Cope, Cret. Vert. 294—Cretaceous, Texas (Marcou, Leidy); Kansas, Arkansas Valley (Cope); Colorado, New Mexico.

Thirteen teeth from Dallas, Tex., and a number of others received from Mr Frank Springer, collected in the vicinity of Las Vegas, in New Mexico, agree well with the descriptions and figures of this species, as given by Leidy. The same species has been referred to the Niobrara chalk of the Arkansas valley by Cope. If his determination and locality are correct the species must be referred to the Benton of Kansas, since the Niobrara does not occur in the Arkansas valley. A single specimen from the Benton of Kansas in the

museum, without definite locality, seems to agree pretty well with the Texas specimens, but the specimen is an uncharacteristic one and may pertain to some other species.

Some of the teeth referred to this species show a marked resemblance to those figured by Woodward (Cat. Foss. Fishes Brit. Mus. I, pl. V, f. 2, *P. rugosus*), and by Dixon (*P. altior* Dix.)

The European species is described as having the sides of the median elevation of the crown smooth, which is not the case with the present species, the grooves continuing midway into the lateral granulations.

Ptychodus, sp. Plate XI, figs. 2, 3; plate XIII, fig. 53.

Four teeth of moderately large size, from the Benton Cretaceous, of Salt creek, Russell county, and two others of smaller size, also from the Benton, seem to belong to a species distinct from any hitherto known. The larger ones will be distinguished from those referred to the upper series of *P. martini*, which are of nearly the same size and shape, by the smaller area of transverse ridges, and the much larger area of marginal reticulations, which are coarser. The teeth are more nearly square and the convexity of the crown is greater. The two teeth of smaller size probably belong with the others. It is possible that some of these teeth may belong with *P. polygyrus*.

The other described species of this genus are the following:

Ptychodus mammilaris Agassiz.—Senonian, Turonian, and Cenomanian, Europe.

Ptychodus rugosus Dixon.—Senonian, England.

Ptychodus decurrens Agassiz.—Senonian, Turonian, and Cenomanian, Europe.

Ptychodus multistriatus Woodward.—Senonian and Turonian, England.

Ptychodus latissimus Agassiz.—Turonian and Senonian, Europe.

Ptychodus papillosus Cope, Cret. Vert, 294.—Upper Cretaceous, Colorado.

Ptychodus triangularis Reuss.—Upper Cretaceous, Bohemia.

Ptychodus levis Woodward.—Lower Chalk of England.

SCYLLIIDÆ.

The family Scylliidæ comprises small sharks with sharp-pointed cuspidate teeth, arranged in numerous series. The following genera are given by Woodward (Cat. Foss. Fishes Brit. Mus. I, 338): *Paleoscyllium* Wagner, Lower Kimmeridgian of Bavaria; *Scyllium* Cuvier, Turonian and Senonian; *Pristiurus* Bonaparte, Lower Kimmeridgian of Bavaria; *Mesiteia* Kramb., Senonian and middle Eocene;

Chiloscyllium Müller and Henle, Molasse; *Crossorhinus* Müller and Henle, Gault; *Cantioscyllium* Woodw, Turonian; *Ginglymostoma* Müller and Henle, Danaian, Eocene.

Numerous teeth from the Lower Cretaceous of Kansas seem in all probability to belong in this family, and agree pretty well, though rather large, with the teeth of *Scyllium*, to which I refer them provisionally.

Scyllium rugosum, n. sp. Plate VI, fig. 5.

Central cusp broad, pointed, nearly symmetrical, the cutting edges nearly straight, one of them a little longer than the other and slightly convex near the tip; a single pair of lateral denticles, which are nearly equilaterally triangular in shape; principal cusp with six or seven strong ridges on the basal two-fifths; denticles with four or five similar ridges reaching two-thirds of the way to the apex; root narrow, apparently not at all produced at the angles; thinned and not at all tumid.

Type No. 1949, U. S. National Museum, Greenleaf sandstone at Greenleaf ranch.

Height of middle cusp	7 mm.
Width of same at base	4 "
Height of denticles	3 "
Width of same	2½ "

Scyllium planidens, n. sp. Plate VI, fig. 7.

Central cusp broad, pointed, convex from side to side, with sharp, non-crenulate edges; lateral cusps sharply pointed, smooth, two in number; root thin, narrow, moderately produced below the posterior denticle, smooth.

Height of median cusp	4 mm.
Width of same at base	3 "
Width of base of tooth	6 "
Height of denticles	1½ "

Type No. 1949, U. S. National Museum. From same horizon as the preceding species.

I refer provisionally to this species numerous other specimens from the same horizon and collection. They differ in the relative size of the denticles, the more posterior direction of the main cusp, and the size. One tooth seems to lack the anterior denticle, which is always the smaller of the two; its absence may be due to injury.

Scyllium (Lamna?) gracilis, n. sp. Plate VI, fig. 6.

Main cusp elongate, slender; inner surface smooth, gently convex longitudinally, more so transversely, with sharp, smooth edges, the interior edge nearly straight, the posterior somewhat concave; denticles

of nearly equal size, small, slender, acute; base narrow, prolonged into a slender root at each extremity.

Height of tooth	9 mm.
Length of middle cusp	6 "
Width of same at base	3 "
Length of denticles	2 "

One specimen, No. 1949, U. S. National Museum, with the preceding species.

LAMNIDÆ.

The Lamnidæ comprise the largest and most voracious of the sharks, represented by a number of species in the oceans of the present time. They are elongated fishes, the dorsal fin without spine; there is no nictitating membrane to the eye, and the gill openings are wide. The teeth are solid in the adult, and are 300 or more in number. The teeth are found very commonly in the Cretaceous deposits of Kansas, as elsewhere, usually scattered singly, though occasionally found more or less connected by the calcified cartilage of the jaws in several rows. Owing to the great variation of size and shape of the teeth in the same individual, it is often difficult or impossible to correctly determine the forms. Doctor Eastman has recently figured and described the nearly complete dentition of *Oxyrhina mantelli*, the most common species of the family in Kansas. Doubtless similar variations will be found in the different species of the other genera of this family.

Oxyrhina.

This genus differs from *Lamna* only in the prevailing absence of the lateral denticles of the teeth. The teeth are large. The genus occurs from Jurassic to the present time.

Oxyrhina mantelli. Plate XIII, figs. 41–46; plate XIV, figs. 2–2m.

Oxyrhina mantelli (Geinitz) Agassiz, Poiss. Foss. III. 282, pl. XXXIII, ff. 1–5, 7–9; Eastman, Paleontographica, XLI, 149–192, pll. XVI–XVIII (where additional extensive synonymy will be found); Woodward, Proc. Geol. Assoc. XIII, 196—Cenomanian, Senonian and Turonian of Europe; Kansas, Texas, New Jersey, Alabama, Colorado, etc.

Oxyrhina extenta Leidy, Ext. Vert. Fauna, 302, pl. XVIII, ff. 21–25.

"Moderate-sized, stout, three-cornered teeth; the crown on the outer side nearly flat, with one or more vertical wrinkles; on the inner side, lightly convex and smooth; root long, thick, low, moderately deeply furcate, usually obtuse at the ends, and on both sides more or less flattened." Eastman, l. c.

This species is very common in the Kansas Niobrara, in fact, the most common of all, and not infrequently it is represented by many associated teeth. From the plates, and from Eastman's figures, it will be readily identified in all its forms.

Lamna.

Teeth, except some of the hindmost ones, with a narrow, compressed, conical cusp, with one or two pairs of small, pointed denticles.

Some of the following species may belong to *Odontaspis*, which can hardly be distinguished by the teeth alone, differing only in the relatively less high and less subulated character of the anterior ones, and in the usually larger size of the lateral denticles.

Lamna appendiculata. Plate XIV, figs. 3–3c.

Otodus appendiculatus (Roemer) Agassiz, Poiss. Foss. III, 279, pl. XXXII, ff. 1–25; Davis, Trans. Roy. Dubl. Soc. IV, 402, pl. XLI, ff. 1–11.

Lamna appendiculata Woodward, Cat. Foss. Fishes Brit. Mus. I. 393; Proc. Geol Assoc. XIII, 196 – Senonian, Cenomanian, Turonian (?), Danian of Europe, Niobrara of Kansas, and Greensand of New Jersey.

"Teeth robust, with a thick root, having a much flattened postero-inferior face, the nutritive foramen not in a groove. Outer face slightly convex or flat, often with a few indefinite vertical folds on the basal half; inner side of crown markedly convex, smooth; cutting edges prominent; a single pair of lateral denticles, broad, but pointed. Anterior teeth narrow and upright; lateral teeth much inclined backward, the anterior teeth much more arcuate and longer than the posterior ones." Woodward, l. c.

Several teeth from the Niobrara chalk agree sufficiently well with the foregoing description, and especially with Woodward's figures, to permit their allocation here. They are somewhat broader than the specimens figured by Woodward. Two of the specimens differ markedly from the others in having the base flatter and the roots much less prolonged downward, the notch of the base shallower and shorter. Another tooth from the base of the Benton, in the conglomerate containing the specimens of *Corax curvatus* and *Ptychodus janewayii*, agrees well with these last specimens and apparently belongs to the same species, if distinct. Their resemblance to *Odontaspis kopingensis* Davis likewise cannot be denied, but the lateral denticles are more triangular in shape.

Lamna sulcata. Plate VI, figs. 1–1b.

Otodus sulcatus Geinitz, Char. Schicht. u. Petriffact. saechs-boehm Kreideb. Nacht 5, pl. IV, f. 2.

Otodus divaricatus Leidy, Ext. Vert. Fauna, 305, vol. XVIII, ff. 26–28; Cope, Cret. Vert. 295.

Lamna sulcata Woodward, Cat. Foss. Fishes Brit. Mus. I, 398 (where additional synonymy will be found); Proc. Geol. Assoc. XIII, p. 197—Cenomanian and Turonian, England, France, Belgium, Saxony, Bohemia; Senonian, England; Cretaceous, Texas, (Leidy); Jewell county, Kansas (Cope); Mississippi (Cope).

"Teeth very robust, the crown sometimes attaining a height of nearly 50 mm. Outer face of crown slightly convex, generally uneven; both the inner and the outer faces with more or less prominent

series of vertical wrinkles near the base, usually irregular. A single pair of large, acuminate lateral denticles, slightly divergent, often incompletely separated from the principal cone. Root with a considerable inward prominence immediately below the base of the crown." Woodward, l. c.

"A name given to very large, robust teeth with vertically wrinkled crown and slightly divergent acuminate lateral denticles. There are specimens in the British Museum from undetermined horizons in the chalk of Kent, Surrey, and Sussex." Woodward.

This species is unknown to me. Its occurrence in Kansas is given on the authority of Cope. The horizon is evidently the Benton.

Lamna mudgei.

Lamna mudgei Cope, Cret. Vert. 207, pl. XII, ff. 11, 12—Niobrara of Kansas, Greensand of New Jersey.

"Indicated by three teeth from the Niobrara epoch of Kansas and one from the Greensand No. 4, from New Jersey. These teeth are rather stout, especially at the base, and the crown is not very elongate. The root is excessively protuberant, projecting horizontally beyond the convex side, and flat or truncate below the protuberance. The enamel is entirely smooth. Length, 14 mm."

This species is unknown to me, or unrecognizable from the description and figures of the mutilated type specimens.

Lamna macrorhiza.

Lamna macrorhiza Cope, Cret. Vert. 297, pl. XLII, ff. 9, 10; Woodward, Cat. Foss. Fishes, Brit. Mus. I, 399—Niobrara of Kansas, Albian of England, Cenonian of S. E. Russia (Woodward).

"Teeth of small size, elevated though robust, the maximum total height being about 25 mm. Outer coronal face flat, or nearly so, with a faint median longitudinal elevation, and often a few folds at the base; inner coronal face very convex, smooth; cutting edges sharp; a single pair of relatively large, narrow, acuminate lateral denticles, divergent, also often marked at the base by minute vertical folds; root with a prominent inward projection below the base of the crown; nutritive foramen in a groove."

The above description by Woodward is drawn from a European specimen, while the type described and figured by Cope is from Ellis county, Kansas, probably Niobrara. I do not know the species.

Lamna (*Odontaspis ?*), sp. Plate XII, fig. 5.

A single tooth from the Lower Cretaceous (Kiowa shales, Clark county), resembles the figure of *Odontaspis kopingensis* Davis, as figured by that author (Trans. Roy. Dubl. Soc. IV, XXXVI, ff. 27, 28), except that it is smaller and has the base rather more prominent, more triangular, and more pointed. The tooth has also resemblance to

Lamna appendiculata, but the denticles are stouter (compare Woodward, Proc. Geol. Assoc. XIII, pl. VI, f. 26). Height of crown, 15 mm.; width of base, 18 mm.; width of base of crown, 9 mm.; distance between points of denticles, 14 mm.

Lamna, sp. Plate XII, fig. 6.

A somewhat injured tooth, of larger size than the last, differs in having a larger and stouter base, the inner projection in the middle of the latter stouter and broader, and the lateral denticles smaller and more obtuse. Height of tooth (approximately), 32 mm.; width of base of crown, 12 mm.; width of base of tooth, 25 mm.

One specimen, Kiowa shales, Clark county.

Lamna quinquelateralis.

Lamna quinquelateralis Cragin, Colorado College Studies, V, 189.

"The specific name *quinquelateralis* is applied to a species of shark whose vertabræ differ from all others of which I have any knowledge. The type vertebra is short, much broader than high, shallow-cupped, and more or less sharply pentagonal ended.

"Measurements: Height, 20 mm.; length, 12 mm.; breadth, 12 mm. The two upper angles measure each about 130 deg.; either lateral angles about 105 deg.; the lower angle is broad and rounded."

"Occurrence: A single vertebra of this form was found by the writer at Belvidere, Kan., with the above-described remains of *Plesiochelys*, in the upper part of No. 4 of the Belvidere section."

Probably this vertebra belongs with one or the other of the above-described teeth from these same deposits, but the correlation cannot be made until the teeth and vertebræ are found associated, which may be long hence.

Scapanorhynchus.

Rhinognathus Davis, Trans. Roy. Dubl. Soc. (2) III, 480.

Scapanorhynchus Woodward, Cat. Foss. Fishes Brit. Mus. I, 351, 1889.

? *Mitsukurina* Jordan, Proc. Calif. Acad. Sci. Zool. I, 1898; Amer. Naturalist, XXXIV, 234.

The genus *Scapanorhynchus*, first proposed by Davis under a preoccupied name, has been more closely defined by Woodward. The teeth themselves cannot in many cases be generically distinguished from those of *Odontaspis*, under which name some were originally described.

Recently Doctor Woodward* has identified a modern genus of sharks, from the deep sea off Yokahama, Japan, with this supposedly extinct type—*Mitsukurina* Jordan.

Possibly the positive identification is premature, but there seems to be no doubt of the close relationship of the two forms, at least.

* Am. Mag. Nat. Hist. III, 487 (1899).

Scapanorhyncus rhaphiodon. Plate VIII, fig. 4; plate XIV, fig. 5.

Lamna (Odontaspis) rhaphiodon Agassiz, Poiss. Foss. III, 296, pl. XXXVIIa, ff. 12-16.

Scapanorhynchus rhaphiodon Woodward, Cat. Foss. Fishes Brit. Mus. I, 353 (where additional synonymy will be found); Proc. Geol. Assoc. XIII, 196—Cenomanian, Russia and Galicia; Cenomanian and Turonian, France, Saxony, and Bohemia; Cenomanian-Senonian, England; Upper Cretaceous, S. India; Upper Cretaceous of Texas, Mississippi, New Jersey; Benton Cretaceous of Kansas.

Lamna texana Roemer, Kreideb. von Texas, 29, pl. I, ff. 7; Leidy, Rep. U. S. Geol. Surv. I, 304, pl. XVIII, ff. 46-50; Cope, Cret. Vert. 296.

Teeth of considerable size, slender, the anterior ones without lateral denticles; inner coronal face conspicuously and finely striate.

A number of teeth before me from the Cretaceous of New Jersey and one from the Benton Cretaceous of Kansas agree fairly well with the figures given by Leidy of specimens from Mississippi, New Jersey, and "from near the mouth of Vermilion creek, in Kansas," and which agree with those from Texas called *Lamna texana* by Roemer.

The specimens agree so well with the European species, especially as figured by Woodward (l. c., I have no European specimens for comparison), that I think there cannot be much doubt of their identity, a conclusion suggested by Woodward.

The Kansas specimen described by Leidy was said to have been obtained by Hayden from a "gray sandstone from near the mouth of Vermilion river." The Vermilion in Kansas runs its whole length through the Carboniferous in eastern Kansas; nor do I think there is any gray sandstone (necessarily Dakota Cretaceous) in the state which will yield these teeth. In all probability the specimens did not come from this state. However, a specimen in our collection agreeing with the species was obtained in the state, and probably from the Benton, though possibly from either the Niobrara or Fort Pierre.

Corax.

The genus *Corax* is confined wholly to the Cretaceous, and is known from the teeth only. Its distinction from *Galeocerdo*, under which name some of its species have been described, is based upon the solidity of the teeth—those of *Galeocerdo* have a hollow cavity within. The teeth are small, compressed, more or less triangular, with marginal serrations, though this character may be more or less wanting in young individuals. They vary not a little in shape in the same individual. In some the crown is nearly bilaterally symmetrical, but they more usually have the crown directed more or less obliquely backward, the anterior margin convex, the posterior more or less straight and angulated.

Three species of the genus are known in England—*C. falcatus*, *C. pristodontus*, which is hardly distinct, and *C. affinis*. In addition, *C.*

antiquus Desl., *C. incisus* Egert., *C. lævis* Gieb. and *C. pygmæus* Munst. have been described from Europe, and *C. crassidens* Cope and *C. hartvelli* Cope from the United States.

Corax falcatus.

Corax falcatus Agassiz, Poiss. Foss. III, 226, pl. XXVI, f. 14, XXVI*a*, ff. 1-15; Woodward, Cat. Foss. Fishes Brit. Mus. I, 424 (where additional synonymy will be found); Proc. Geol. Assoc. XIII, 198, pl. VI, ff. 13-15.

Galeocerdo falcatus Leidy, Ext. Vert. Fauna West. Terr. 301, pl. XVII, ff. 29-42.

Cenomanian and Turonian, England, France, Switzerland, Saxony, Bohemia, Galicia, Russia; Senonian of England and France; Cretaceous of Texas, New Jersey, Mississippi; Niobrara of Kansas.

The very variable shape of the teeth referred to this species will be seen in plate XIII, ff. 1-40. Possibly the specimens there figured represent distinct species. *C.* (*Galeocerdo*) *crassidens* Cope seems to be represented by fig. 24, and *C.* (*Galeocerdo*) *hartvelli* Cope (Cret. Vert. 244) by fig. 23. Possibly this species also includes *C. pristodontus* and *C. lindstromi*, both of which seem to be imperfectly differentiated from *C. falcatus* at present.

In plate XIV, ff. 1-1*l*, are shown a number of teeth pertaining to a single individual and found associated with many others, by Mr. Martin, in the Niobrara Cretaceous of the Smoky Hill valley. Isolated teeth of this species are the most abundant of the selachian teeth in the Niobrara of Kansas. Only in very few instances have many teeth been found associated, so that it is yet impossible to fully understand the dentition. The species occurs rarely, if at all, in the lower Niobrara horizons, where those of *Oxyrhina* and *Ptychodus* are the most abundant.

Corax curvata, n. sp. Plate XII, figs. 7, 8.

Two specimens from the same block which yielded those of *Ptychodus janewayii* and *Lamna* species, *antea*, seem evidently specifically distinct from the foregoing. These teeth, while not differing much in outline from certain ones referred to *C. falcatus*, show a marked variance in structure. In *C. falcatus* the outer surface of the tooth stands out but very slightly. In *C. curvata* the crown is attached to the root very obliquely, so that when resting upon a plane the tooth forms a high arch, touching only by the extreme tips of the roots and crown. The inner surface, also, is very much more uneven and convex, the crown separated from the root by a marked, narrow, transverse ridge, which is scarcely indicated in the teeth of *C. falcatus*. Altitude, 8 mm.; greatest width, 14 mm.; horizon, lower or lowermost Benton of Ellsworth county.

Leptostyrax, **gen. nov. Plate VI, figs. 3, 15, 15a; plate VIII, fig. 7.**

Leptostyrax bicuspidatus, **gen. et sp. nov.**

Principal cusp long and slender, flattened upon the outer side, with sharp, smooth edges and a median convexity in the middle of the flattened surface; for the most part convex longitudinally, gently concave before the apex. Inner surface strongly convex from side to side, concave on the lower half longitudinally, gently convex on the upper part. A single denticle present, slender, flattened cylindrical, with an anterior and posterior carina; it arises below the base of the main cusp, and is directed more outwards, its inner surface concave longitudinally. Immediate base of crown of both main cusp and denticle with short ridges. Base of tooth short, truncate (?) below the main cusp, prolonged downward below the denticle. Length of main cusp, 19 mm.; width of same at base, 5 mm.; length of denticle, 5 mm.; width of same at base, 2½ mm.; height of tooth, 26 mm.; width of base, 10 mm.

A small tooth of the same form found with this has a total length of 14 mm. The base is deeply emarginate below, with two slender roots; that below the denticle the longer. Mentor beds, 4½ miles southwest of Marquette, Kan.

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PLATE VI.

Fig. 1, 1*a*, 1*b*.—*Lamna sulcata* Geinitz, after Leidy, natural size.

Figs. 2, 2*a*.—*Scapanorhynchus rhaphiodon* (*texana*) Agassiz, natural size, after Leidy.

Fig. 3.—*Leptostyrax bicuspidatus* Willist., from the side, natural size.

Fig. 6.—*Scyllium* (*Lamna ?*) *gracilis* Willist., enlarged.

Figs. 7, 8.—*Scyllium planidens* Willist., enlarged.

Fig. 5.—*Scyllium rugosum* Willist., enlarged.

Figs. 9, 10.—Fragments of undetermined teeth from Kiowa shales.

Fig. 11.—*Cœlodus stantoni* Willist., imperfect right splenial dentition, natural size.

Fig. 12.—*Cœlodus brownii* Cope, imperfect left splenial dentition, natural size.

Figs. 13, 13*a*.—Amphibian atlas from Laramie Cretaceous.

Fig. 14.—Undetermined shark tooth (*Corax ?*) from Benton of Colorado, enlarged.

Figs. 15, 15*a*.—*Leptostyrax bicuspidatus* Willist., natural size.

Middle figure of plate—Selachian vertebra (*Corax ?*) from Niobrara Cretaceous.

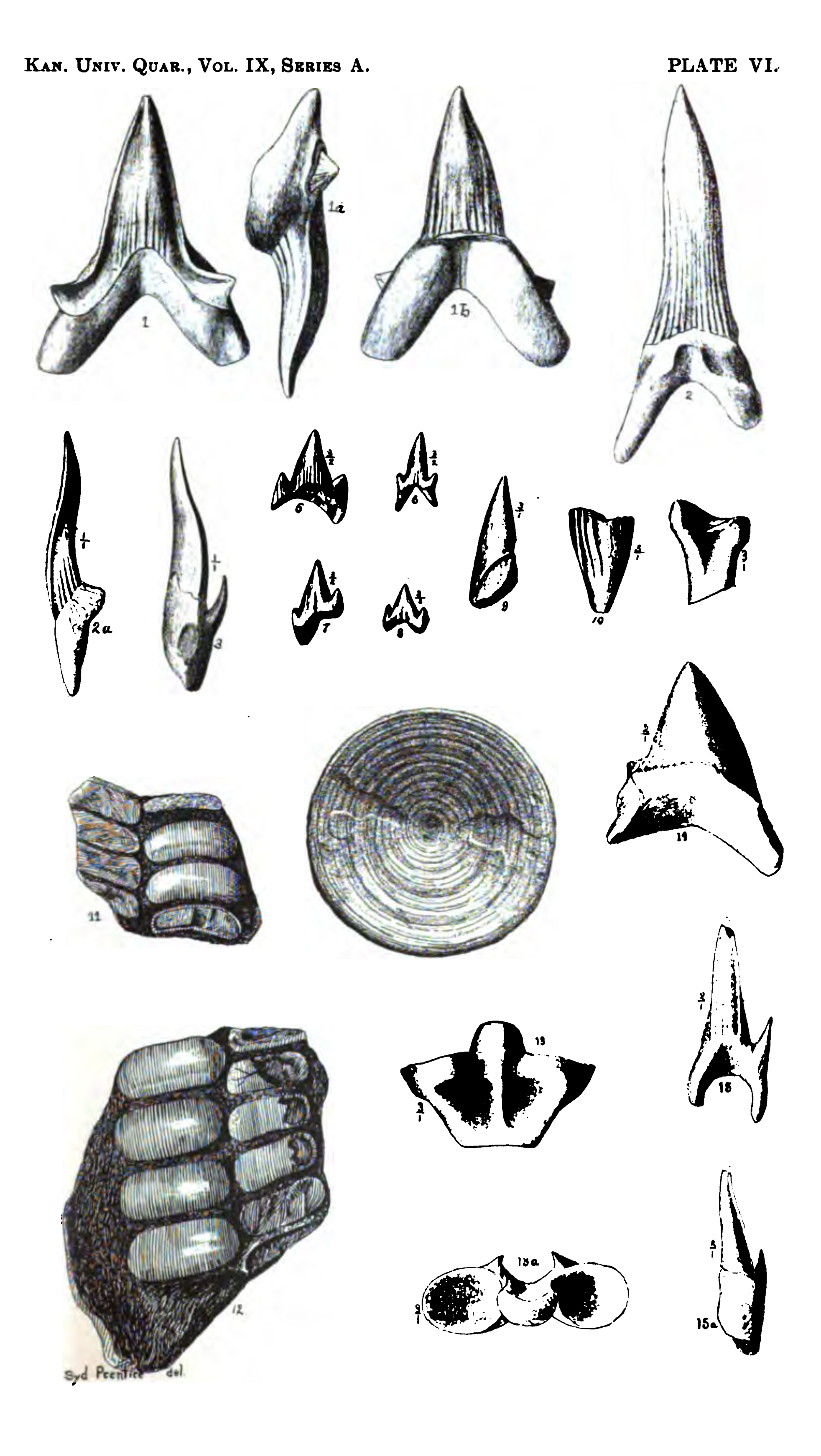

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1b
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PLATE VII.

Ptychodus mortoni Mantell, natural size.

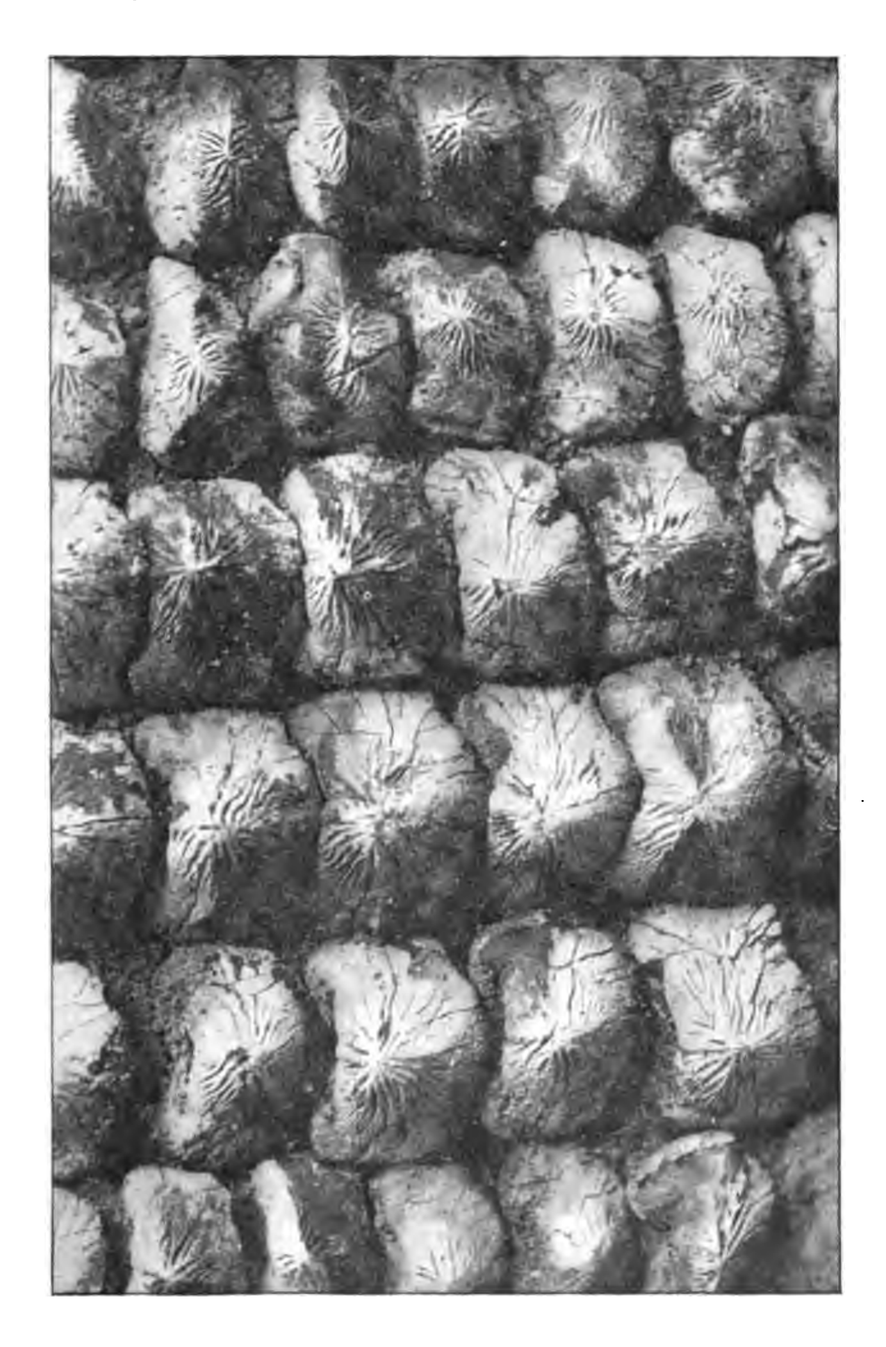


PLATE VIII.

Fig. 1.—*Ptychodus mortoni* Mantell, part of dentition of upper jaw, as preserved in the matrix, four-sevenths natural size.

Figs. 2, 4.—*Scapanorhynchus rhaphiodon* Agassiz, natural size.

Fig. 3.—*Lamna appendiculata* Agassiz, natural size.

Fig. 5.—*Oxyrhina mantelli* Agassiz, natural size.

Fig. 6.—*Cœlodus stantoni* Willist., crowns of two teeth from internal row, lower jaw, much enlarged.

Fig. 7.—*Leptostyrax bicuspidatus* Willist., enlarged.

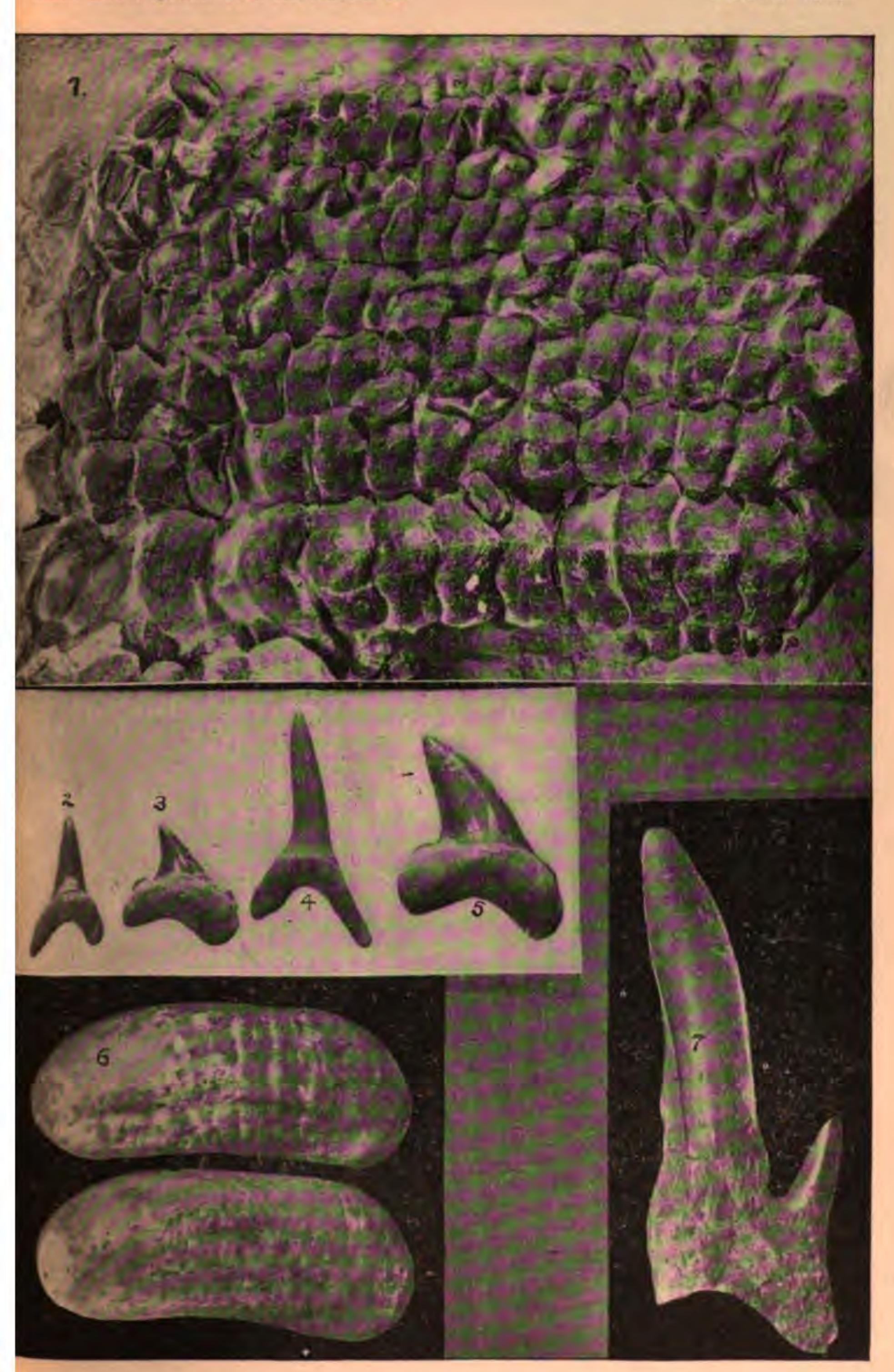
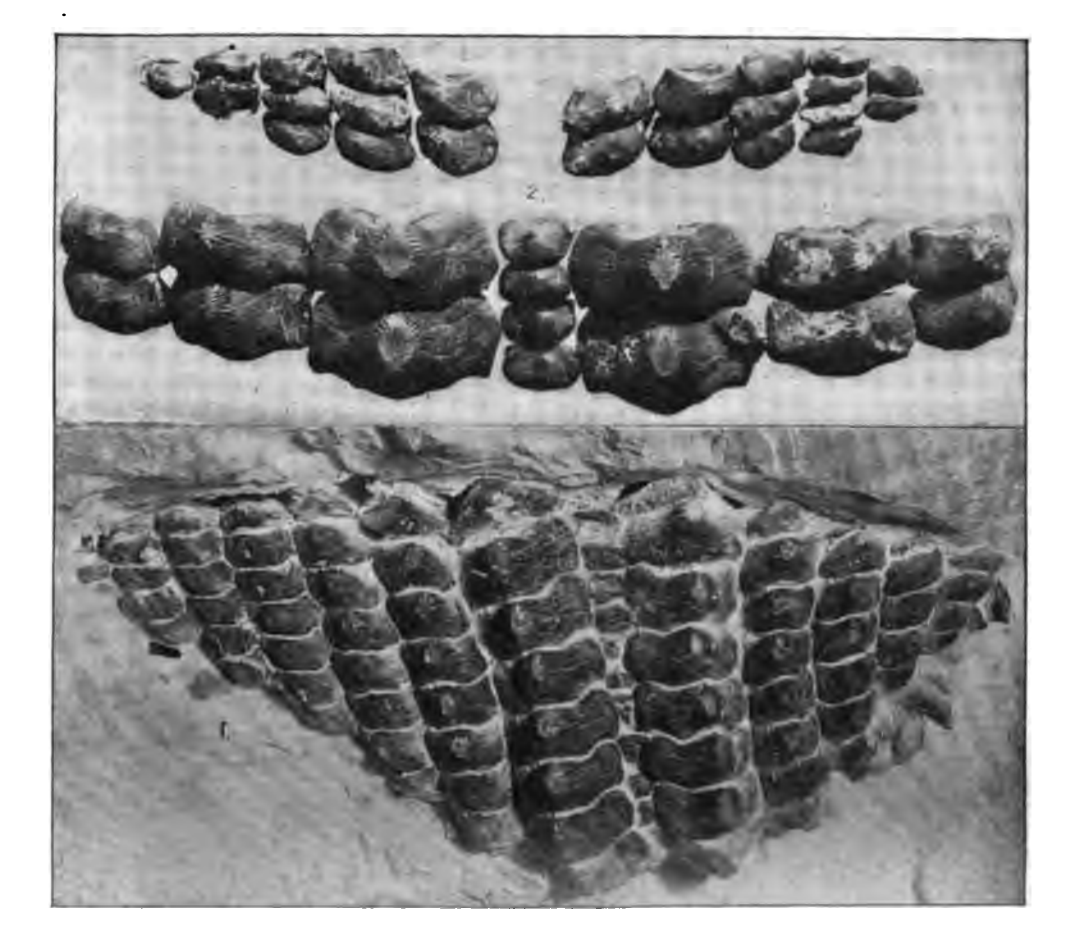

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PLATE IX.

Fig. 1.—*Ptychodus mortoni*, end of superior dentition, continuous with left end of fig. 1, plate VIII, but less reduced.

Fig. 2.—*Ptychodus mortoni*, a transverse series of teeth, arranged more loosely, from near the right extremity of fig. 1, plate VIII, about two-thirds natural size; the upper series belong one at each end of the lower series.



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PLATE X.

Ptychodus martini Willist., three-fourths natural size; the teeth were discovered disassociated.

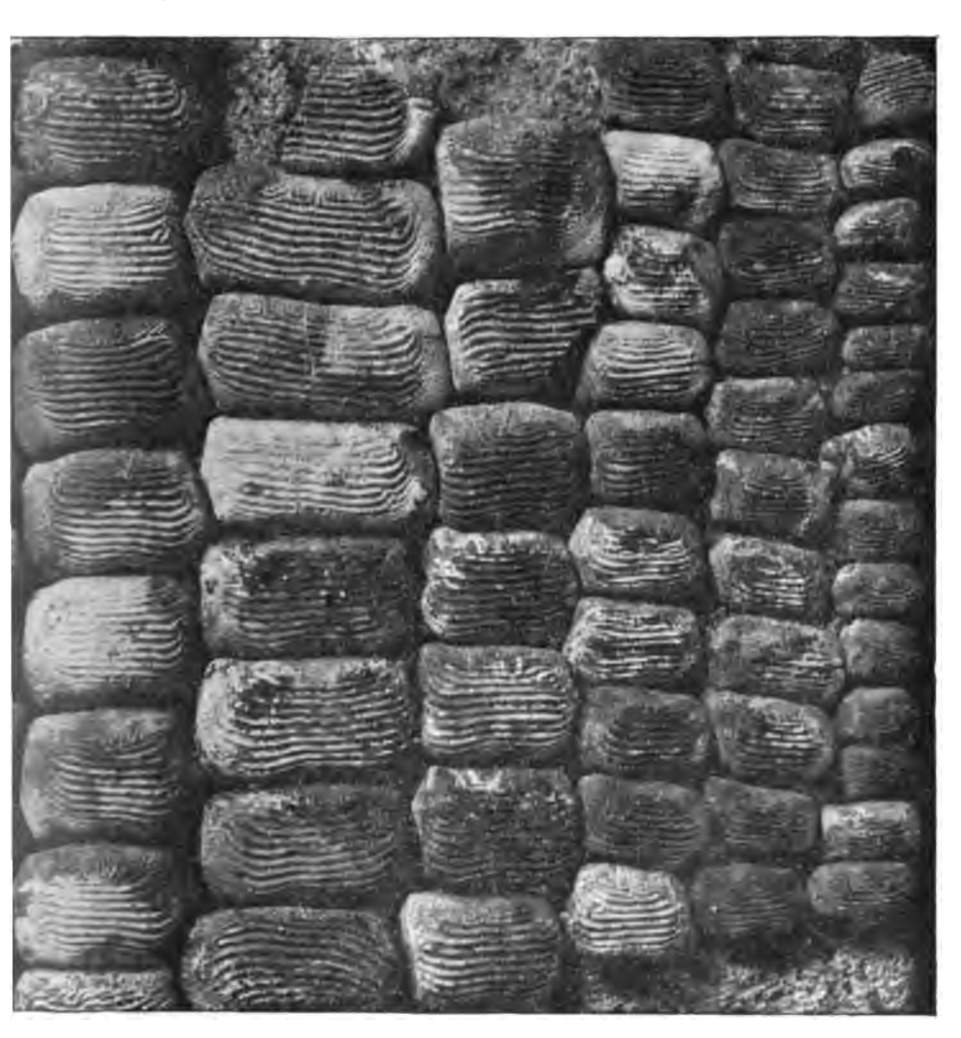


PLATE XI.

Figs. 1, 2, 3.—*Ptychodus*, sp. indet.

Fig. 4.—*Ptychodus occidentalis* Leidy, natural size.

Fig. 5-8.—*Ptychodus anomymus* Willist., natural size.

Fig. 9.—*Ptychodus polygyrus* Buckl., a little enlarged.

Figs. 10-15.—*Ptychodus whippleyi* Marcou, nearly natural size.

Figs. 16-18, 20-22, 24.—*Ptychodus anonymus* Willist., nearly natural size.

Figs. 19, 23, 25, 26, 27.—*Ptychodus*, spp.


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PLATE XII.

Figs. 1–3.—Undetermined lamnids from Kiowa shales, Lower Cretaceous, enlarged one-half.

Fig. 4.— ? *Mesodon abrasus* Cragin, enlarged one-half.

Figs. 5, 6.—*Lamna*, sp., from Kiowa shales, enlarged one-half.

Figs. 7, 8.—*Corax curvatus* Willist., from without and within, enlarged nearly two diameters.

Figs. 9–11.— ? *Ptychodus janewayii* Cope, enlarged.

Fig. 12.—*Lamna*, sp., enlarged nearly two diameters. Kiowa shales.

Fig. 14.—*Ptychodus polygyrus*, from the side, natural size (the same tooth figured on plate XI, fig. 9).

Fig. 13.—*Ptychodus occidentalis*, enlarged nearly two diameters.

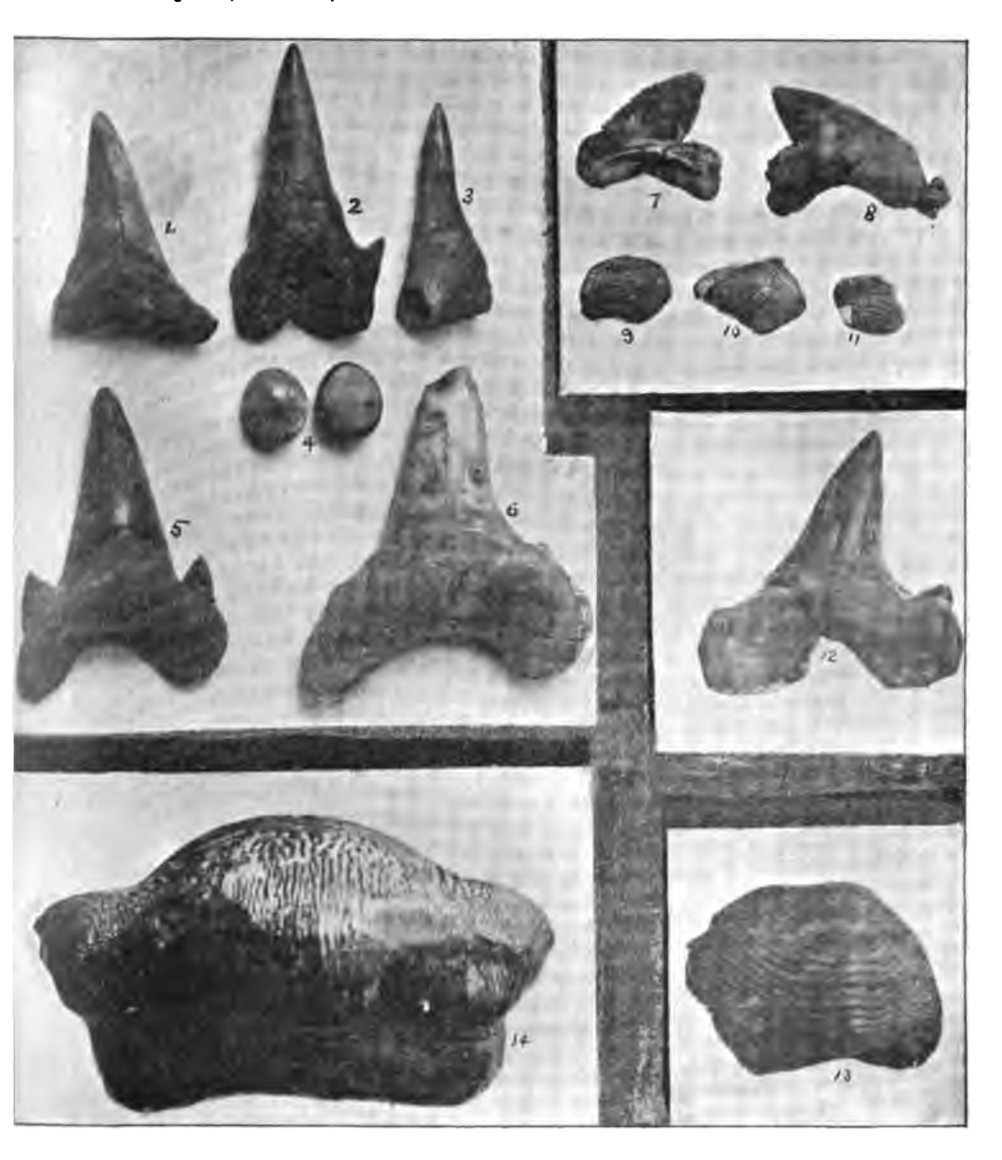

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PLATE XIII.

Figs. 1–40.—*Corax falcatus* Agassiz, about nine-tenths natural size; isolated teeth from many individuals.

Figs. 41–46, 50–52.—*Oxyrhina mantelli* Agassiz, nearly natural size.

Figs. 47–49.—*Lamna appendiculata* Roemer, nearly natural size.

Fig. 53.—*Ptychodus*, sp., enlarged one-fourth.

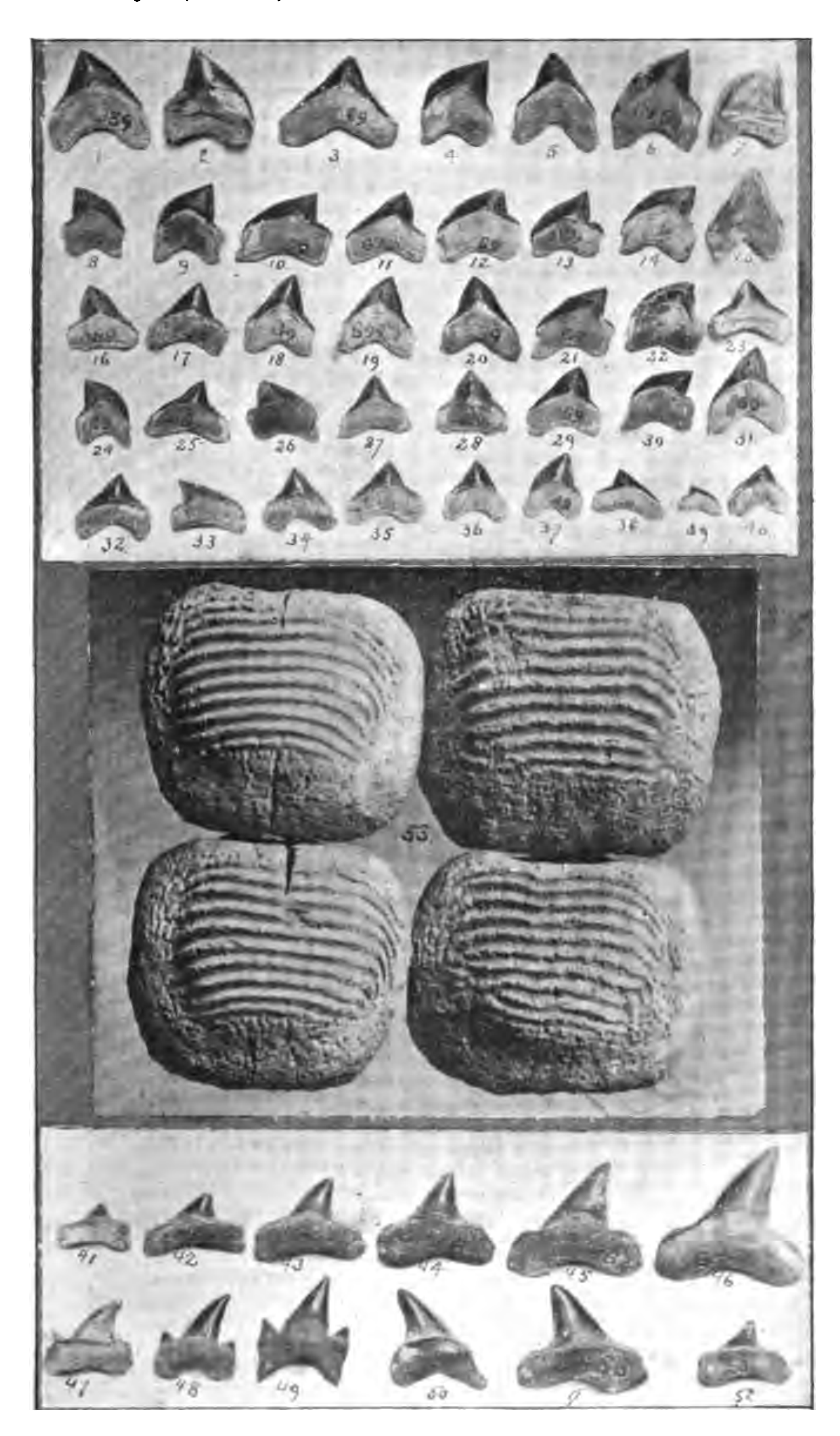


PLATE XIV.

Figs. 1-1*l*.—*Corax falcatus* Agassiz, from a single individual.
Figs. 2-2*l*.—*Oxyrhina mantelli*, from a single individual.
Figs. 3-3*c*.—*Lamna oppendiculata.*
Figs. 4, 5.—*Scapanorhynchus rhaphiodon* Agassiz.
Figs. 6, 7.—*Oxyrhina mantelli.*
All six-sevenths natural size.

PLATE XIV.


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NOTE ON THE PERMIAN FLORA OF KANSAS.

Contribution from Paleontological Laboratory No. 54.

BY E. H. SELLARDS.

DURING the past year a very interesting and important plant horizon was discovered in the Permian (Marion* formation), Dickinson county, Kansas, by Mr. Charles Sterling, of the University. In October of the same year the author visited the locality and made a careful collection. The plants are of great biological as well as geological interest.

Callipteris conferta Sterng. occurs very abundantly. *C. conferta*, var. *obliqua* Goep. is the most common. Other forms occur which agree closely with *C. conferta lanceolata* Weiss and *C. conferta vulgaris* Weiss. Still other pinnæ, differing from any yet figured, in having a much more obtuse apex, a proportionally smaller terminal pinnule, and a flexuous rachis, seem to represent a new variety of this very variable species. The largest specimen of the species in our collection is the middle portion of a frond, having a rachis 6 mm. wide, with pinnæ alternate, oblique, 2 cm. apart. The pinnules are alternate, contiguous almost to the apex, 8 to 11 mm. long, and stand out obliquely from the rachis, curving back at the apex. Another specimen shows the terminal portion of the frond, with the characteristic appearance as figured by Weiss.†

The pinnules, seen from above, have a smooth coreaceous look, the midvein and rachial vein showing as slight depressions; seen from below they appear wrinkled, the midvein of the pinnule and the rachial vein showing as sharp, thin elevations. Professor Weiss speaks of a line running from the rachis of the pinna to the incision between the pinnules. Our specimens show that this line is a vein going off from the midvein of the pinnule near or at its base, or from the rachis of the pinna, and running obliquely to the incision between the pinnules. It is impossible to mistake the species, as it agrees in every particular with Weiss's figures. The fronds are readily recognizable by the form of the pinnules, the strong vein running to the incision between them, and the decurrent pinnules attached to the penultimate rachis between the ultimate pinnæ.

*Chas. S. Prosser, Journal of Geology, vol. 3, p. 786.

† Fossile Flora d. jungst. Stein. u. Roth, pls. VI and VII.

Some specimens belonging to the Tæniopteroid group of ferns are of especial interest as showing what is, so far as I have been able to learn, a new type of fructification among ferns. The fronds are all simple, linear, 10 to 20 or more cm. long, strongly petiolate, and have a Tæniopteroid venation. Two species are represented by both sterile and fertile fronds. The sporangia, oval or slightly elongate, are situated on the back of the frond, midway between the veins, apparently sessile, half immersed in the coaly epidermis of the frond. When removed from the frond, their position is marked by a cup-shaped depression. The sporangia on one species are about three-fourths mm. apart, five or six between each two veins. On the other species they are closer, about one-half mm. apart, sixteen to eighteen between each two veins. On many of the sporangia a transverse slit is seen across the top or slightly to one side, very similar to the slit for the discharge of spores on many living ferns of the eusporangiate type.

A very remarkable group of herbaceous ferns occur abundantly in the collection. They are all small plants, 10 to 30 cm. high, with pinnatifid or simply pinnate fronds. They comprise three species, and by their form are referable to the family Alethopterideæ. They probably should be referred to a new genus.

Other genera present, so far as determined, are *Neuropteris*, *Odontopteris*, *Pecopteris*, *Sphenopteris*, *Sphenophyllum*, and a fragment of leaf belonging to the *Cordaites* group.

The geological range of *Callipteris conferta* has an interesting bearing on the question of the age of the uppermost paleozoic rocks of Kansas. The species is characteristic of the middle and lower Rothliegenden of Europe, but has not been found above the middle of the Permian. It has also been found in the Permo-carboniferous of West Virginia. The occurrence of this species near the top of the Kansas strata together with *Sphenophyllum*, a genus that has not been discovered above the middle of the Permian, makes it improbable that the Kansas beds are younger than middle Permian. While, on the other hand, the presence of *Callipteris*, a Permian genus, and the number and variety of plants belonging to the Tæniopteroid group, as well as the general character of the flora, tends to confirm the Permian age of the Kansas Upper Paleozoic.

The author is at present, and has been for some time, working on the collection, and hopes in the near future to have more definite results and more satisfactory information in regard to this interesting flora.

ON THE CONSTRUCTION OF COLLINEATIONS.

BY H. B. NEWSON.

1. INTRODUCTION. On page 137 of Reye's Geometrie der Lage (Holgate's translation), is found the following pair of dualistic theorems:

Two conics which lie in the same plane and have one point S in common are correlated projectively to each other if those points of the curves are made to correspond, which lie in a straight line with S. Every common point of the curves different from S is a self-corresponding point. The point S is likewise a self-corresponding point if the curves have a common tangent in this point, *i. e.*, if they touch each other at S.

Two conics which lie in the same plane and have a common tangent s are correlated projectively to each other if those tangents to the two curves are made to correspond, which intersect in s. Every common tangent to the two curves different from s is a self-corresponding line. The line s itself is self-corresponding only if the curves have a common point of contact in s.

In vol. IV, page 243, of this journal. I deduced the converse of the theorem on the right, and showed how by its use to construct the five types of collineations in the plane. In the Annals of Mathematics, vol. XI, page 148, Prof. Arnold Emch deduced both theorems from the properties of the congruences (1, 3) and (3, 1) of lines in space.

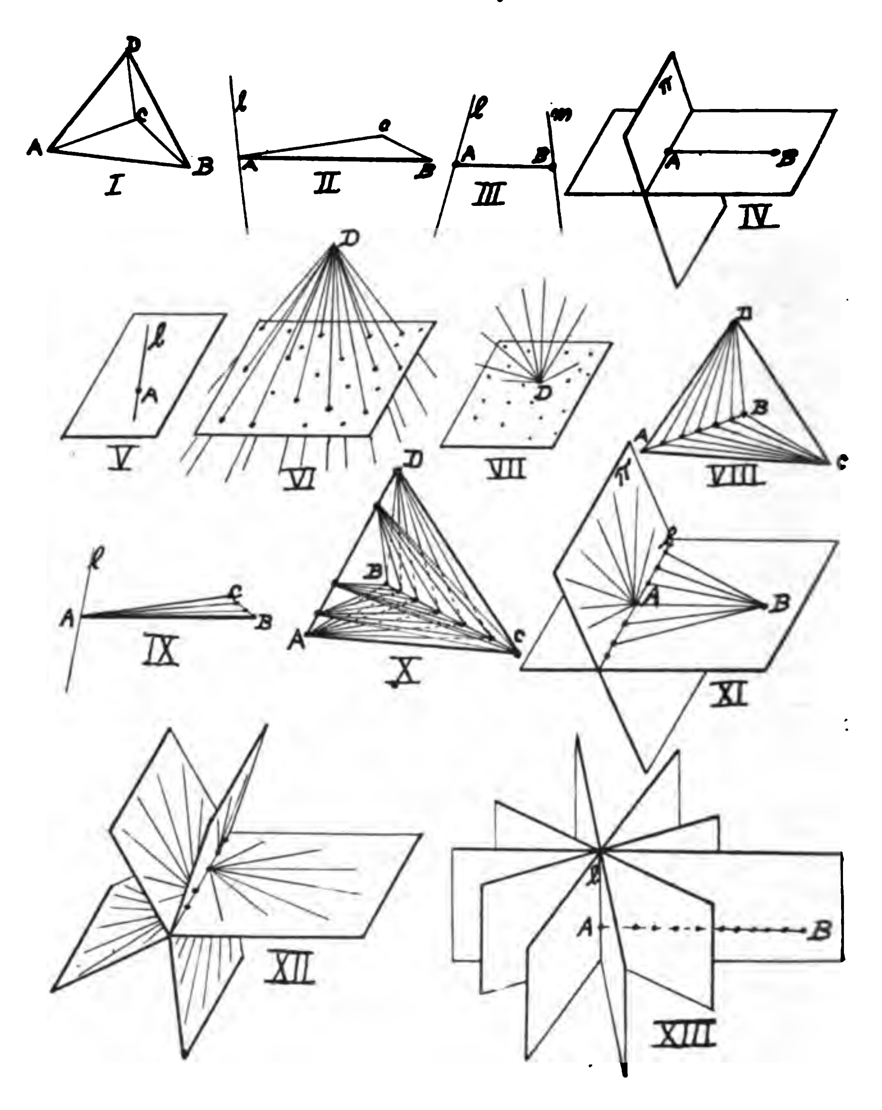
The object of this paper is to construct the five types of collineations by means of the theorem on the left, and to develop the analogous method for constructing the thirteen types of collineations in space.

A.—COLLINEATIONS IN THE PLANE.

2. CONSTRUCTION BY MEANS OF TWO CONICS. Let there be given two projectively related conics K and K_1 intersecting in a real point S. By making use of the principle that corresponding points on K and K_1 are collinear with S, we can construct the line g_1 corresponding to any line g of the plane; we can also construct the point P_1 corresponding to any given point P.

The line g cuts K in Q and R; join Q and R to S; these joins cut K_1 in Q_1 and R_1 corresponding points to Q and R. The line joining Q_1 and R_1 is the line g_1 which corresponds to g. If a point P be given, we find P_1 by drawing two lines g and g' through P cutting K; find by the above construction the corresponding lines g_1 and g'_1; these intersect in P_1, the point which corresponds to P.

If the line g cuts K in a pair of imaginary points, the construction of g_1 may be accomplished by choosing two points G and G' on g and constructing their corresponding points G_1 and G'_1; these new points



determine g_1. If g is tangent to K, g_1 will be tangent to K_1 and the two points of contact will be collinear with S. If the given line g passes through S and cuts K in P and K_1 in P_1, the corresponding line is found by joining P_1 to S_1 the point where the tangent to K at S cuts K_1.

Theorem 1. *A collineation or projective transformation of the plane can be completely constructed by means of two conics K and K_1 intersecting in S.*

3. Invariant Points and Lines. The conics K and K_1 intersect in S and generally in three other points A, B, C. Since any line

through S cuts K and K_1 in a pair of corresponding points, it follows that A, B, and C are self-corresponding or invariant points on K and K_1. In other words A, B, and C are invariant points and the lines AB, BC, and CA are self-corresponding or invariant lines of the collineation. Hence in the most general case a projective transformation of the plane leaves invariant the vertices and sides of a triangle.

The three points A, B, and C are either all real or one is real and two are conjugate imaginary; for the real conics K and K_1 intersect either in four real points, in two real and two conjugate imaginary points, or in two pairs of conjugate imaginary points. Since S is real, A, B, and C are either all real or one is real and two conjugate imaginary.

Theorem 2. *A real collineation in its most general form leaves a triangle invariant which is real in all of its parts or has one real and two conjugate imaginary vertices.*

4. Five Types of Collineations. The five well-known types of collineations in the plane are obtained by taking the two conics K and K_1 in different special relations to each other. Thus when the two conics K and K_1 of the above construction intersect in four points we have what is called type I. This type has two sub-types, hyperbolic and elliptic, according as the invariant triangle is real in all its parts or partly real and partly conjugate imaginary.

If the two conics have contact of the first order, as for example when A and B coincide, the transformation is said to be of type II. If the two conics intersect at S and have contact of the second order at a point A, the invariant figure is a lineal element A_1, and the transformation is said to be of type III.

If the conics K and K_1 have contact of the first order at S, then the common tangent to K and K_1 at S is an invariant line; also the lines joining S to the other two points of intersection are invariant lines of the collineation. Thus we have three invariant lines through S and one invariant line not through S. The transformation of this type is a perspective collineation with its vertex at S and its axis through the other two points of intersection of K and K_1; it is said to be of type IV. If K and K_1 have contact of second or third order at S, the collineation is still perspective but with its vertex on its axis; it is said to be type V.

Theorem 3. *The construction of a collineation by means of two conics K and K_1 gives rise to five distinct types of collineations, according to the mutual position of the two conics.*

5. ∞^2 Constructions of the Same Collineation. Any given collineation T can be constructed in ∞^2 different ways, as we proceed to show. There are ∞^2 conics passing through the three invariant

points A, B, C. From these ∞^2 conics one can form ∞^4 pairs of conics; out of these ∞^4 pairs of conics ∞^2 pairs will give rise to the same collineation. For let us choose any conic L passing through A, B, C. The transformation T constructed by K and K_1 transforms L into L_1, intersecting L in A, B, C, and V. The course of reasoning used above shows that corresponding points on L and L_1 are collinear with V. Hence the two conics L and L_1, may be used to construct the collineation T in the same way that K, K_1, and S were used. It is evident that to each of the ∞^2 conics through A, B, and C there is a corresponding conic, and hence there are ∞^2 different constructions of the same transformation T.

Theorem 4. *A collineation T can be constructed by means of a pair of intersecting conics in ∞^2 different ways.*

6. COLLINEATION CONSTRUCTED BY MEANS OF TWO CIRCLES. The collineation constructed by means of two intersecting circles K and K_1 is an interesting special case. Without giving the proofs I shall state only the results, leaving the reader to work out the details. This special collineation transforms angles into equal angles and parallel lines into parallel lines; it also increases or diminishes all areas by a constant ratio, which is equal to the ratio of the radii of the two circles. In case the circles are of equal radii the collineation is equivalent to a rigid motion of the plane into itself.

B.—COLLINEATIONS IN SPACE.

7. TWO INTERSECTING SPACE CUBICS. Let us suppose that a given collineation in space transforms a point S into S_1 and S_1 into S_2. The bundle of rays through S is transformed into the bundle through S_1. The two bundles (S) and (S_1) are projectively related and hence (Reye's Geometrie der Lage, Zweite Abtheilung, *S.* 87.) the locus of intersection of those corresponding rays which do intersect is a twisted cubic C passing through both S and S_1. In like manner the original bundle through S_1 is transformed into the bundle through S_2; and the corresponding intersecting rays generate a second cubic C_1 passing through S_1 and S_2. Since the bundles through S and S_1 are transformed into the bundles through S_1 and S_2 respectively, it follows that the cubic C is transformed into the cubic C_1.

The line SS_1 is a common ray of the two bundles through S and S_1; considered as a ray of the bundle through S it is transformed into the tangent to C at S_1; but considered as a ray of the bundle through S_1 it is transformed into the line S_1S_2. Hence the tangent to C at S_1 intersects C_1, and S_2 is this point of intersection.

Consider a point P on C and its corresponding point P_1 on C_1. The lines SP and S_1P are corresponding lines in the two bundles through S and S_1, since they meet on C. But S is transformed into

S_1 and P into P_1; hence the line SP is transformed into S_1P_1. Therefore S_1P and S_1P_1 must coincide, since they each correspond to SP. Hence P and P_1, corresponding points on the two cubics C and C_1, are collinear with S_1. From this it is evident that the two cubics C and C_1 lie on the same quadric cone with vertex at S_1.

Theorem 5. *A collineation T in space which transforms a point S into S_1 and S_1 into S_2 transforms the cubic C into C_1; C and C_1 intersect in S_1 and lie on the same quadric cone with vertex at S_1; a pair of corresponding points on C and C_1 are collinear with S_1.*

8. CONSTRUCTION OF A COLLINEATION BY MEANS OF C AND C_1. By making use of this last theorem we can construct the plane p_1 corresponding to any given plane p. The plane p cuts C in three points P, P', P''; join these three points to S_1; these joins cut C_1 in P_1, P'_1, P''_1, corresponding points to P, P', P''. Pass a plane through P_1, P'_1, P''_1 and this is p_1, the plane which corresponds to p.

To construct the line g_1 corresponding to any given line g in space, pass two planes through g and by the above method construct their corresponding planes; these intersect in g_1 the required line. To construct the point P_1 corresponding to any given point P in space, pass three planes through P and construct their corresponding planes; these new planes intersect in P_1.

If a plane p cuts C in one real and two conjugate imaginary points, only the point corresponding to the real point of intersection can be constructed. In this case we can choose two other real points in p and construct their corresponding points; thus p_1 is determined.

If the plane p is tangent to C, the corresponding plane p_1 will be tangent to C_1 and the two points of contact will be collinear with S_1. If the given plane passes through S_1 and cuts C in P and P', the corresponding plane p_1 will pass through P_1 and P'_1 and the point where the tangent to C at S_1 cuts C_1, *i. e.*, at S_2.

Theorem 6. *A projective tranformation of space can be completely constructed by means of two cubics C and C_1 intersecting in a point S_1 and lying on the same quadric cone with vertex at S_1.*

9. INVARIANT POINTS, LINES, AND PLANES. Two cubics C and C_1 lying on the same cone K intersect at its vertex and generally in four other points A, B, C, D. This may be shown as follows: Two twisted quartics on the same surface F of the second order intersect in eight points. When F degenerates into a cone, each quartic degenerates into a cubic and an element of the cone. The vertex of the cone is a double point on each degenerate quartic and hence counts for two intersections. The points in which the elements belonging to each cubic intersect the other cubic count for two more points of intersec-

tion of the quartics; thus we have left four points of intersection of the two cubics.

Since any element of the cone K cuts C and C_1 in a pair of corresponding points, it follows that A, B, C, D are self-corresponding or invariant points of the collineation. In the general case these four points form a tetrahedron. It is at once evident that the four faces of the tetrahedron are invariant planes and the six edges are invariant lines of the collineation.

Theorem 7. *A collineation T constructed by means of two cubics C and C_1 leaves invariant in the general case the vertices, faces and edges of a tetrahedron.*

10. THE FIVE PRIMARY TYPES OF COLLINEATIONS. There are thirteen types of collineations in space, each characterized by its invariant figure. When the two cubics C and C_1 intersect in four distinct points, the collineation T constructed as above is of type I. If two points of intersection of the cubics C and C_1 coincide but not at the vertex of the cone, the collineation is of type II. If the four points of intersection A, B, C, D coincide two and two, the collineation is of type III. If three of the four points of intersection coincide, the collineation is of type IV. If all four points of intersection coincide, the transformation is of type V. These constitute what are called the five primary types of collineations in space.

11. If one of the four points of intersection of C and C_1 coincides with S_1, the vertex of the cone, the common tangent to C and C_1 at S_1 is an invariant line of the collineation. The lines joining S_1 to the three remaining points of intersection B, C, D are likewise invariant lines; thus there are four invariant lines through S_1, and therefore all lines through S_1 are invariant lines of the transformation. All points of the plane B, C, D are also invariant points of the transformation; hence our transformation T in this case is of type VI. In case two of the four points A, B, C, D coincide at S_1 so that the plane of invariant points passes through S, we have a collineation of type VII. These two cases are both perspective collineations.

12. THE SIX REMAINING SECONDARY TYPES. The cone K on which the cubics C and C_1 lie may degenerate into two intersecting planes. The two cubics in this case each degenerate into a conic and a line l, respectively l_1, not in the plane of the conic, meeting the conic in a single point. The two conics lie in the same plane and generally intersect in four points $SABC$. The two lines l and l_1 coincide throughout and pass through one of the points of intersection, say A, of the two conics.

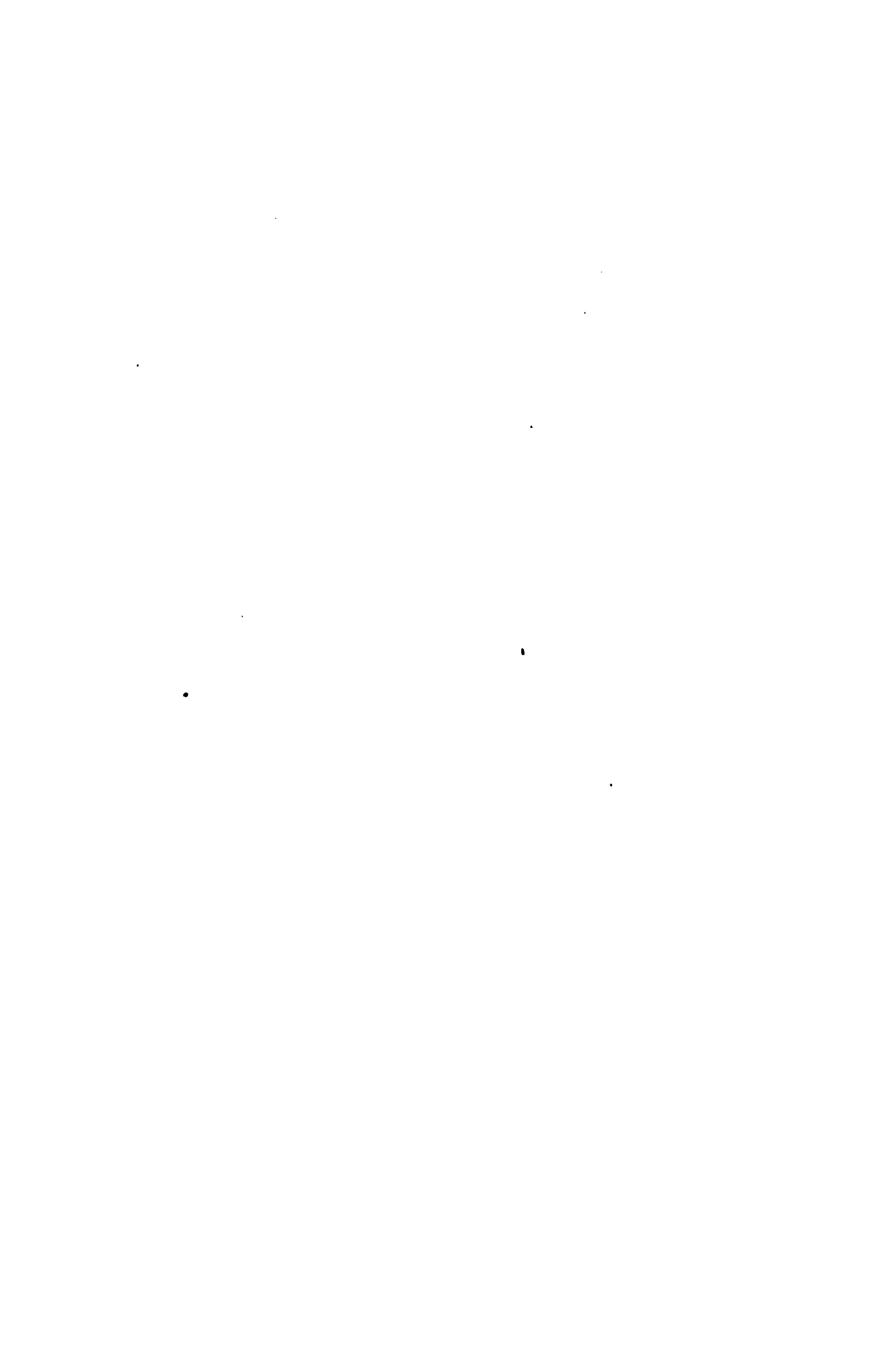
The collineation constructed by means of these two degenerate

cubics leaves invariant all points on the line ll_1 and the triangle ABC. Such a collineation is of type VIII. If B and C coincide the collineation is of type IX. If A and B or A and C coincide the collineation is of type XI. If A with ll_1 through it coincides with S_1 the collineation is of type X. If A, B, and C all coincide the collineation is of type XIII. If A and B both coincide with S the collineation is of type XII. In each of these types the invariant figure has at least one line of invariant points.

Theorem 8. *The method of constructing a collineation in space by means of two twisted cubics lying on the same cone gives rise to all of the thirteen known types of such collineations.*

13. ∞^3 Different Constructions of the Same Collineation. The construction of a given collineation T by means of the two cubics C and C_1 is evidently not unique. The vertex S_1 of the cone on which the cubics lie may be any point in space. For each point in space there is a different pair of cubics by means of which a transformation T can be constructed; in other words there are in the general case ∞^3 different constructions of the same transformation T.

14. Collineations with the Same Invariant Tetrahedron. Passing through the five points $ABCDS$ there are ∞^2 cubics; for a cubic is determined by six points and each point counts as a double condition. There are ∞^1 cones of second order with vertex at S_1 and passing through $ABCD$. On each cone there are ∞^1 of the cubics through the five points; hence on each cone there are ∞^2 pairs of cubics, each pair giving rise to a different collineation with the same invariant tetrahedron $ABCD$. Since there are ∞^1 such cones, there are ∞^3 collineations which have the same invariant tetrahedron.



THE SPERMATOCYTE DIVISIONS OF THE ACRIDIDÆ.

BY C. E. M'CLUNG.

With Plates XV, XVI, XVII.

OWING to the importance of the question with regard to the mechanism of heredity, the manner in which the chromatin is separated in the two rapidly succeeding spermatocyte divisions has attracted much attention. In the consideration of this problem, materials derived from *Ascaris megalocephala*, different species of Copepods and several genera of insects have been largely used. The results thus obtained are of a widely different character; indeed, all the possibilities of the process appear to have been exhausted in the explanations of different observers.

Fundamentally, the question involved might be stated somewhat in this form: Given a rod; derive from it by direct division four approximately equal rods. Obviously this might be accomplished by splitting the rod twice longitudinally in planes at right angles to each other, by cutting it across in three places, or by splitting it once longitudinally and then halving each of the resulting pieces by a cross-division.

The problem of securing from the spireme thread of the spermatocytes the quadripartite chromosomes which enter into the subsequent divisions has, in fact, thus been solved by different investigators. The work of these scientists is now so well known that it is hardly necessary to review it here, but in order to make a consideration of the question more convenient, I will briefly advert to typical cases.

The simplest method, that of two longitudinal divisions, finds its exponent in Brauer, who reached his conclusions from a study of the spermatogenesis of *Ascaris megalocephala*. In this animal, it is asserted that the spireme thread divides by cleavage at right angles to its length, into a number of segments equal to that of the subsequent chromosomes. Each of these segments, then, by two divisions parallel to the length of the original thread, splits into four rods, which remain bound together by linin fibers. The two divisions of the spermatocytes then distribute these to the four resulting spermatids. This conclusion, although apparently well substantiated, remains an almost isolated example, and, owing to the fact that the composition of the chromosomes in the sexual cells of this worm is so anomalous, it

seems to me that any results derived from a study of this object should not be accepted unless well supported by similar appearances in other animals.

The other possibilities are such as have found expression from investigations upon insect material and that of other Arthropods. Wilcox, from a study of the genera *Melanoplus* and *Cicada*, becomes an advocate of the formation of the tetrads by the second possibility, *i. e.*, by repeated cross-divisions. As in the case of *Ascaris*, there is little to support this view in the appearances found in other objects.

The remaining explanation, according to which the tetrad is formed by one longitudinal and one cross-division, is advocated by Henking, vom Rath, and Häcker, and more recently by Paulmier and Montgomery. These authors are all in agreement upon the question of the two forms of division, but are in dispute as to whether the longitudinal or the cross-division is first to occur.

It is the purpose of the present paper to contribute to the existing observations upon these disputed subjects and to offer some explanations suggested by the study of Orthopteran spermatogenesis, as manifested in the Acrididæ. The principal object of study has been *Hippiscus phœnicopterus*, but the facts observed in this form have been verified by examination of numerous other genera, so that what is here given may, I think, be considered typical for the family.

I.—MATERIALS AND METHODS.

The first specimens of *Hippiscus* were captured early in the spring. These were either adults, or nymphs in the final period of their transformation, which had wintered over in this stage. The condition of the testes in the two forms was essentially the same. In the follicles of the first individuals taken most of the cells were in the prophases of the first spermatocyte division, and had evidently endured the winter in this condition, for, after a few days of warm weather, large numbers of the cells were observed passing through the later stages of division. The continuance of the spireme during the hibernation of the animal was further confirmed by observations upon nymphs of the second moult taken in the fall. Here a great portion of each follicle was found to be filled with cells established in the spireme stage.

I cannot refrain from calling attention to the very excellent character of the material conveniently offered by this widely distributed insect for the study of spermatogenesis. The cells are even larger than those of the *Amphiuma* testis and are much more favorable for observation on account of the smaller size of the organ and lesser number of nuclear elements.

For fixing the tissue, a variety of agents was employed, but all were finally discarded in favor of the osmic acid mixtures of Hermann

and Flemming. Gilson's aceto-nitric-sublimate fluid, however, gave very satisfactory results.

For staining, Heidenhain's iron-hæmatoxylin method was largely and most satisfactorily employed. This was supplemented by the use of Flemming's triple stain, which is very valuable for indicating the chemical condition of the cellular elements during division.

II.—NOMENCLATURE.

In order to avoid misunderstandings concerning the different steps in the process of spermatogenesis, I will briefly outline the nomenclature that I employ. This, as will be observed, is the one proposed by la Valette St. George. According to it, the cells arising from the primordial germ cells are designated as spermatogonia up to the time when they cease dividing for a period and undergo a considerable increase in size. The exact period at which the cells of this generation pass over into the next is marked by the reconstruction of the daughter cells of the last division, during which the spermatogonial chromosomes are diffused into material for the formation of the spermatocyte spireme.

This is a clearly indicated change in the material that I have studied, for the following reasons: (1) There is a marked difference in the staining reaction of the spermatogonia and that of the other cell generations, both in the resting condition and during division. This consists in a stronger general affinity for the coloring matters as manifested by all the cell elements, so that the region of the testis occupied by these cells presents a deeper coloration than other portions. (2) The cells, because of the rapidity with which they divide, are smaller than those of the succeeding cell generations, and the nuclei occupy a relatively larger area. (3) The number of chromosomes* is the same as that of the body cells, and during division the elements are rod-shaped and split in elongated halves. (4) The spindle is shorter and its outline broader than that of the spermatocyte division figures. (5) The centrosomes are often more clearly distinguishable during the spermatogonial division than they are in later ones.

Immediately after the last spermatogonial division the cells cease to divide, and, during a considerable length of time, merely increase in size. These cells are the spermatocytes. In *Hippiscus*, the cells of the testis pass through the winter in the prophases of this stage. Early in the spring they commence to divide vigorously, and in the division figures the number of chromosomes is but half that of the spermatogonia. The spermatocytes which have quadripartite chromo-

*The material derived from *Hippiscus* is not suited to the determination of numerical ratios, owing to the large size and loose distribution of the elements. I therefore accept the authority of other investigators, pending the search for a favorable object.

somes, and which, therefore, are the earliest to divide, are called the "first spermatocytes." Those having diad chromosomes in the metaphase are denominated "second spermatocytes." By the division of these the spermatids are formed. There is no resting condition of the cells between the two divisions of the spermatocytes.

When the two spermatocyte divisions are completed, the end of cell division is reached, and the subsequent changes undergone by the cells are merely transformations. These changes are experienced by the spermatids, and, at the completion of their metamorphosis, they become spermatozoa, the mature elements of the male sexual organs.

Regarding the stages of the division processes, I recognize four, depending upon the condition of the chromatin. These are (1) the prophase, during which the chromatin takes on the form of a thread and then divides by cross-division into a number of segments called chromosomes. This stage terminates and (2) the metaphase begins when the chromosomes become arranged in the equatorial plate. The metaphase witnesses but a single change in the chromatin, the separation of the halves of the chromosomes. As soon as this is completed and the daughter groups of chromosomes commence their movement towards the two poles it is ended, and the succeeding stage, (3) the anaphase, is inaugurated. This comprises all the movements of the chromosomes from their position in the equatorial plate until they are grouped at the two poles of the spindle; here it ends, and the final stage, (4) the telophase, commences. These terminal changes, included under the telophase, consist usually in a loss of the identity of the chromosomes, the arrangement of the resulting chromatin in a nuclear vesicle such as is characteristic of the resting cell, and the separation of the halves of the mother cell by the growth of a cell wall. This cycle of changes terminates and the next one commences when the chromatin of the daughter cells leaves the diffuse condition and inaugurates the formation of a spireme.

In the spermatocytes, of course, there is no resting condition between the divisions, and therefore no reconstruction of the nuclei, so that the termination of one cycle and the commencement of another is marked, principally, by the growth of a cell wall between the diasters. Applying this method of designating stages in the process of cell division to the cells of the insect testis, we would mark the end of the spermatogonial divisions by the changes which result in the reconstruction of the nuclei and the formation of cell walls between the last cells that divide with the somatic number of chromosomes in the mitoses. The prophases which succeed this division belong to the spermatocytes and have nothing further to do with the spermatogonia. I am thus explicit in stating my position on this point because Mont-

gomery, in his late paper upon the spermatogenesis of Pentatoma (**8**), commences his consideration of the spermatocytes with the anaphases of the spermatogonia. To the treatment of this part of the subject by Montgomery I shall have occasion to refer later.

It will be noticed that I make no reference to the so-called "synapsis" stage. It is thus slighted because I have good reasons to regard it merely as an accident in the process of preparation and not as a normal condition of the nuclear elements. At least such is the case in the testicular cells of the Orthoptera.

As stated in a previous paper (**23**), I agree with Montgomery that the designation "chromosome" should not be applied indiscriminately to all chromatic elements that occur in the cell. It is obviously very confusing to have one author denominate a tetrad a chromosome, and to have another apply the same term to each of the elements composing the aggregate. According to the above-mentioned author, the chromosome is a unit prepared for separation in the equatorial plate, and it is to units occupying this position in the cell that the term should be applied, regardless of what they have been or what they are to become. I am much in sympathy with the endeavor to have the term "chromosome" apply to but one clearly defined cell element.

Since, however, the chromosomes are bodies designed to be separated by metakinesis, which do not acquire their full development until the metaphase is reached, I do not hold their origin in the prophases so essential in their determination as does Montgomery. This would be a matter of little moment were it not for the accessory chromosome that occurs in insect reproductive cells. This element, which I consider as much a chromosome as any of the others that come to lie in the equatorial plate, never loses its identity in the prophases as do the others, and so cannot be traced back to an origin from the spireme of that cell, as becomes necessary according to Montgomery's definition.

While subscribing, therefore, to the definition proposed by this investigator, in so far as it concerns the unity of the element in question, I differ from him with regard to the importance that must be attached to the preliminary stages of the formation. It is, of course, impossible to make a definition that will stand accurately for all cases, especially where the knowledge is so scant as it is in the present instance, but for convenience of description it is almost necessary to have some definite statement regarding the views of a writer. I shall, on that account, endeavor to state in a few mords my conception of a chromosome, having in mind the points made by Henking and Montgomery regarding the present value of the element, without questioning its past or prospective relationships.

These considerations would lead me to frame a definition some-

what as follows: A chromosome is one of the chromatin elements of the nucleus formed, usually, during the prophases of mitosis, and divided during metakinesis to form two daughter chromosomes. In this definition the word "element" is understood to signify a unit, simple or compound, separated from the rest and moving as an individual during the later prophases and the anaphases of mitosis. Of necessity, the chromosome of the prophase and that of the anaphase differ. The latter is but half the volume of the former, and in the germ cells has only half its valence, but in one essential they are the same: each is acting as a unit among coordinate units and not merely as a member of one of these. Also, it is regarded that metakinesis is the inauguration of the individuality of the daughter cells, so that, while the cell bodies are not yet separated, the unity of the mother cell has been destroyed and it can no longer be regarded as a simple individuality. The term "chromosome" being, then, restricted to the units of the division figures, there remains no name for the parts composing these when they are compound, as in the tetrads and diads. This is the want which I believe has led to confusing the meaning of the word "chromosome." I find it very difficult to express myself clearly and succinctly regarding the compound elements without having some designation for the component parts. I should like, therefore, to propose the term "*chromatid*" for each of these, so that we might speak of the chromosomes of the first spermatocyte in the tetrad condition as being composed of four "chromatids," while those of the second spermatocyte would contain two. So far as I know, there has been no such word compounded from the familiar etymological materials of cytological nomenclature. I therefore feel free to make use of the term as being both suggestive and convenient.

III.—OBSERVATIONS.

To properly understand what takes place during the spermatocyte mitoses, it will be necessary to examine the last of the spermatogonial divisions, particularly the anaphases and the telophases, for in them is the material that is directly transformed into that of the spermatocytes.

In all of the specimens examined the spermatogonia occupied the distal portion of the follicles. Here they are plainly to be observed, on account of their smaller size, denser color, and large number of chromosomes. The purpose of this article does not require a discussion of the spermatogonia, and, accordingly, the anaphases of the last division will suffice for a beginning of the present discussion.

Here the long, looped chromosomes lie loosely in the cell, but so entangled that it is difficult to enumerate them. Figs. 1 and 2 show the cells at this stage of their growth. Unlike the spermatogonia of

Xiphidium, there is as yet no noticeable appearance of the accessory chromosome so strikingly visible in the spermatogonia of the Locustidæ.

Immediately following the assembly of the spermatogonial chromosomes at the poles of the mother cell, they commence to disintegrate in preparation for the formation of the nuclear thread of the spermatocyte. This is a very interesting process, and was carefully observed in a follicle where the relative position of the cells clearly indicated the phases of development.

The first thing to be noted is the change in the character of the chromosomes. Heretofore smooth in outline and homogeneous in structure, they now become irregular in form and of a granular nature. A little later it will be seen that the dispersion of the chromatic material has progressed so far that almost all trace of the individual chromosome has disappeared. Only here and there does a slight massing of the chromomeres indicated the position of a former chromosome. (Fig. 4.)

Such, however, is not the fate of all the chromatic elements. One, refusing to give up its identity, maintains its form among the remains of its fellows and passes into the spermatocytes unchanged, to become the accessory chromosome, whose future history will be considered later.

From the scattered mass of chromatin granules produced by the breaking down of the spermatogonial chromosomes, there is now constructed a thin, granular thread which marks a very early stage of spermatocyte prophase. This becomes more definite in outline and thicker in structure until a single, much-convoluted thread is formed. (Figs. 5, 6, 7.) While it is a difficult matter to determine with certainty whether or not the end of this process results in the formation of a single thread, I am inclined to believe that it does.

But however this may be, there is no doubt that shortly afterwards a series of cross-divisions results in the establishment of a number of long, irregular chromatin rods. The number of these is either the same, or very nearly the same, as that of the chomosomes appearing in the spermatocytes. Figs. 8 and 9 show the conditions prevailing at this time. Shortly after this a marked change takes place in these chromatin segments. The coarsely granular character thus far noticeable gives way to a much finer granulation which accompanies a shortening and loosening of the chromatic segments. The chromatin here gradually passes into thread-like processes which extend throughout the nucleus and join the rods and loops together. The form and structure of these elements is subject to considerable variation, as may be observed from an examination of Figs. 10, 11, 12, and

13; but despite the multiplicity of their forms, these precursors of the chromosomes are all referable to a common type.

One thing of striking interest and importance to be observed at this stage is the clear and unmistakable existence of the longitudinal cleft in these segments. This may appear more or less clearly manifest, as is shown in Fig. 12, but there is absolutely no doubt of its presence. Owing to the various positions assumed by the chromatin segments in the nucleus, the split is more easily observed in some than in others or even in different parts of the segment, as is shown in Fig. 14.

There is, in nearly every case, a weak place about the center of the rod or loop. As a result of this, the thread often becomes bent upon itself at an angle (Fig. 14), thus producing the double-V's described by Paulmier. From the method of its formation and subsequent behavior, there is no doubt in my mind that this represents the place where the chromatids of the second spermatocyte division are to separate. Certainly the space between the arms of the V's corresponds to the longitudinal cleft of the thread and to the plane of cleavage in the first spermatocyte division.

The subsequent behavior of these peculiar elements is very interesting and offers us a key by which we may determine whether or not the separation of the chromatids effected by the first spermatocyte division is longitudinal or cross. It is at this point where the greatest difference of opinion concerning the behavior of the chromatin elements exists, and I shall, therefore, speak in detail of the changes now ensuing, in the hope that the observations I have made upon the extremely favorable objects at my command may serve to aid in bringing together and unifying the diverse results obtained by other investigators who have not been so fortunate in the quality of their material. The conclusions herein set forth have been reached only after careful and painstaking observations and I feel convinced of their accuracy.

The method by which the tetrad elements are formed is particularly shown in Figs. 14, 15, 15*a*, and 17. The planes of the two resulting cleavages are clearly indicated in the double-V figure represented in Fig. 14. This will serve as a type figure to which we may refer various modifications for explanation. Instead of being bent at the middle, the element may maintain the form of an approximately straight rod, in which case the point of cross-division is not always apparent. Again, the free ends of the rod may curve around until they come in contact, thus producing the occasional ring figures to be observed in various stages of the first spermatocyte prophases. These latter are particularly valuable in the determination of the longitudinal character of the first division.

In the stages represented in Figs. 15, 15*a* and 17 are brought out several points which I wish to emphasize. It will be noted in several of the elements that the lines of the two divisions are very clearly marked, particularly so in the one represented in Fig. 17. It will also be observed, in this element, that the chromatids have moved upon each other along the line of the cross-division to such an extent that the arms of the resulting cross-figure approximate each other in length. This movement is a very significant one, as I hope to show in considering the later stages of division.

The lines of separation between the chromatids, so plainly apparent in these early stages, entirely disappear with the subsequent concentration of the chromatin elements, and it is only the general outline of the chromosome and a knowledge of its formation that enables us to understand what takes place during division.

A great change in the constitution of the chromosomes occurs as the metaphase of the first spermatocyte division is approached. During the early prophases, the rings, loops and rods occurring in the nucleus all display the diffused granular condition represented in the figures. The essential feature of their further development consists in the concentration of the chromatic material. As a result of this, the elements become smaller and denser and all lines of division between the chromomeres become indistinguishable. This is true not only of those in the same chromatid, but of those between chromatids, so that the chromosomes in the nuclear plate appear to be simple homogeneous bodies.

From what follows in the resulting early anaphases, it would appear that the chromatids of each chromosome are bound together by certain intrinsic forces which maintain a unit element so long as they are undisturbed. The result is an obliteration, but not destruction, of the individuality of the constituent elements. This is very plainly apparent in their later behavior. Thus, immediately after the halves of the chromosomes are separated in the metaphase, the free ends, not attached to the spindle fibers, immediately diverge, showing a line of separation between the two chromatids, which is quite indistinguishable in the apparently simple rod which they constituted.

This coalescence of the elements and their ability to move along each other, as shown in the earlier prophases, put us in possession of the necessary facts to determine the exact character of the spermatocyte divisions.

I now wish to call attention to Figs. 18, 19, and 20, which exhibit the metaphase of the first spermatocyte division. The great variation in the form of the chromosomes was for some time very puzzling, and it was not until I had made out their constitution that I could

understand the meaning of this diversity of form. Once understood, however, the process is one of extreme simplicity. In Fig. 22 I have drawn a number of chromosomes under the camera lucida which show the progressive changes undergone by them during division. Those from *a* to *e* lay in the equatorial plate of one nucleus, and are as clear as diagrams in their indication of the intrachromosomal movements.

At *a*, the chromosome lies with its longer diameter (corresponding to the length of the thread from which it is derived) in the equatorial plane. At its center (which represents the point where the cross-division is indicated in the earlier prophases) are attached the fibers of the spindle. At *b* is shown an early effect of the fiber contraction, which results in the formation of a cross-figure with its longer arm in the equatorial plate (compare this with the chromatin element shown in Fig. 17). A further contraction of the fibers brings about a lengthening of the arms to which they are attached, and a corresponding shortening of those lying across their axis. This continues until the result indicated at *d* is reached. It will be noted that this chromosome has almost exactly the same form as that of *a*, except that its longer diameter lies parallel to the axis of the spindle. The traction exerted by the fibers continues until the halves of the chromosome are separated, as shown in *e*, *f*, and *g*. At *h* is presented a chromosome of the stage represented at *a*, but viewed from the pole of the cell. Imagine the ends of the structure to be brought around until they coalesce, when the ring represented at *i* will be formed.

Knowing the composition of the chromosome, one can easily conceive what takes place during the separation of its halves. It is evident that the chromatids on each side of the longitudinal division, acted upon by the contracting fibers, move along upon each other as they did during the earlier prophase when their structure was less dense and the spaces between them were manifest. That the demarkation between the chromatids was not lost is evident from an examination of Fig. 21. Here it is observable that the diads, shortly after they have separated, exhibit their dual nature by springing apart at the ends not attached to the fibers. This plane of separation doubtless existed in the tetrad, but on account of the cohesive forces prevailing in the element it was not visible. Immediately upon the destruction of the balance of forces there established, however, the elements separated and manifested their individuality.

There is no question, I think, but what the division of the chomosomes in the first spermatocyte of *Hippiscus* takes place as I have indicated, and an examination of many other Orthopteran species leads me to believe that it is the usual method of division in this order. Indeed, I should not be surprised if it were a method com-

mon to all insects. The work of Paulmier makes it almost certain that the processes prevailing in the Orthoptera also obtain in Hemiptera. The rings and crosses figured by many investigators in plant and animal cells might easily be referred to some structure of this character.

Reference was made on an earlier page to the conclusive evidence offered by the ring figures with regard to the character of the first spermatocyte division. This, I think, cannot be disputed. The rings, with the point of cross-division to which the threads are attached indicated by a slight projection, come to lie in the equatorial plate. With the contraction of the fibers the halves of the rings separate more and more, until at the point of final separation the resulting figure differs in no marked degree from that of the rod type.

If the chromosomes of the spermatocytes are formed from the spireme thread by one longitudinal and one cross-division, it might naturally be supposed that it is a matter of little moment which of these separations occurs first. Indeed, it might be thought that the chromosomes could divide indiscriminately in the two spermatocyte divisions, some splitting longitudinally, and some across, in the first spermatocyte mitosis. Such an occurrence has, in fact, been described by some authors.

From my studies of insect spermatogenesis, I am led to believe that such a phenomenon rarely, if ever, occurs. On the contrary, the chromosomes manifest such a constancy of habit as to indicate some fundamental principle in the order of their divisions. What this may be is not now apparent, but it is none the less real, I think. Owing to the peculiar changes undergone by the chromosomes in the first spermatocyte mitosis, it is conceivable that the diverse accounts of different authors may be due to faulty observations upon unfavorable material. Certainly I should ascribe great constancy to the sequence of the divisions, for all manifestations of cellular activity point to definite and characteristic changes in the nuclear elements. I cannot, in the light of my present studies, subscribe to any theory which explains the division of the chromosomes as one of mere mass separation.

A telophase of the first spermatocyte division is represented in Fig. 23. Here it will be noticed that the diads have become grouped together, indistinguishably, into a mass. There is, however, no reason to believe that they, in any way, lose their identity. There is no such thing as a resting stage between the two spermatocyte divisions. As soon as the archoplasm has had time to distribute itself in the daughter cells and these have become separate and distinct individualities, the second spermatocyte division figure is formed. In it, we note just such elements as appear in the anaphases of the first spermatocyte.

Figs. 24 and 25 show the metaphase of the second spermatocyte division. The diad character of the chromosomes is here plainly exhibited, and there is no obliteration of the boundaries between the chromatids, which is so characteristic an appearance of the elements in the first spermatocyte. The chromatids are superimposed upon each other in the plane of the spindle axis so that their separation in metakinesis is a very simple matter. The union of the diad elements seems to be a slight one, their only point of contact, usually, being that at which the fibers of the first spermatocyte division were attached.

The character of the spindle, also, throws some light upon the nature of the chromosomes. It is small and weak compared with that of the first spermatocyte division, showing that the force necessary for the separation of the diad elements is slight. It is also more unstable and transient than that of the preceding cell generation. Figs. 26 and 27 show anaphases of the second spermatocyte. It is noticeable that, with the polar movement of the chromosomes, the spindle is also elongated, so that it stretches throughout most of the length of the cell. As a result of this longitudinal extension, the spindle becomes almost non-existent at the end of the anaphase, being represented only by a few masses of archoplasmic substance.

The telophases are brief, and soon from the second spermatocyte are formed the spermatids which transform directly into spermatozoa. The changes involved in this process are not connected with the spermatocyte divisions, and so will be left for a subsequent paper, where they may be considered in detail.

Only casual mention has as yet been made of the interesting structure described under the name of "accessory chromosome" in a previous paper (**23**). The material for the earlier work was derived exclusively from the Locustidæ, and it was surmised that, although this element might be found in all insects, there would be more or less difference in its form and behavior in various species.

These surmises have been verified by subsequent study. A great many specimens, drawn from the different orders of insects, have been examined, and in no case was the absence of the accessory chromosome noted. On the other hand, considerable differences were found to exist in the general character of the element. Since, however, the material for the present paper was taken from the Orthoptera, comparisons will not be instituted except among the subdivisions of this order.

Some broad differences with respect to this nuclear element exist between the Locustidæ and the Acrididæ. In the former family, as previously described, the accessory chromosome arises some time before the last of the spermatogonial divisions. It may be observed

as a large and striking element of the mitoses of these cell generations some time before the transformation into spermatocytes. Just when it arises, or how, is not known. It appears first in the resting stage of the spermatogonia, and from this time on throughout its whole history it manifests a steady and constant character. In relative size it is always much larger than the other chromosomes, and in staining, it maintains a constancy in striking contrast to them. Its part in the formation of the spermatozoon is conspicuous and apparently important.

In the Acrididæ, the uniformity of staining power and the peripheral position in the nucleus are maintained by the accessory chromosome, but its origin and relative size appear to be different. Instead of appearing during a resting period among the diffused chromatin, it is at first observed as one of the spermatogonial chromosomes persisting in the nucleus, while its fellows break down into a granular mass of chromatin.

Appearing thus in the last series of spermatogonia, it does not exhibit in its peculiar character until the spermatocytes are established. Fig. 4 shows the first stage, so far observed, in the production of the accessory chromosome in *Hippiscus*. Throughout the prophases of the first spermatocyte, it is to be noted as a strongly staining, sharply outlined body, lying directly under the nuclear membrane. In this character and position it persists until it takes its place in the metaphase ready for division. Here it is so much like the rest of the chromosomes that it is impossible to distinguish it from the others. There is, therefore, every reason to believe that it comports itself through the division like its fellow chromosomes. A discussion of its position and character in the spermatid will be reserved for a subsequent paper.

The alluring explanation by Paulmier concerning the function of the accessory chromosome unfortunately receives no support in the behavior of this structure in the Orthopteran testis. If extreme constancy in form, structure and staining reaction is any indication of permanency and importance, then no other cell element excels this one in the possession of these qualities. Every observation made upon members of the Acrididæ, as well as of the Locustidæ, tends to support the view that the accessory chromosome is of primary importance in the development of the spermatozoon. It is almost invariably the case that when a part is in the progress of degeneration it becomes extremely variable and eccentric in its behavior, During all the divisions in which it takes part, the accessory chromosome pursues a uniform course, with the apparent purpose of carrying its substance through to the end of the process with the least possible in-

fluence from the rest of the chromatin. Studies in progress in this laboratory by a student, Mr. W. S. Sutton, show that so strenuous is this endeavor, that during all the spermatogonial divisions the accessory chromosome is provided with a separate vesicle whose contents do not mingle with those of the ordinary nuclear vesicle, except during the actual process of separating the daughter chromosomes. Such a refinement of nicety would, to say the least, be extremely incompatible with our usual ideas of degeneration. Some more immediate connection with the idioplasm than is enjoyed by the ordinary chromosome, it seems to me, would be a more probable explanation of the accessory chromosome's behavior than would one which regards it as possessing the evidence of degeneration.

In respect to the function of this remarkable element, nothing definite can as yet be said. By its formation, it is removed from the influences operating upon the rest of the chromatic material during the long-continued prophases of the first spermatocyte division. This is the time when the fundamental differences in chromosome structure between the germ cells and the somatic cells are inaugurated, and during this time the accessory chromosome remains apart and distinct from the rest of the chromatic material. It thus seems to be the conserver and bearer of certain properties which it is desirable not to have disturbed during the early phases of the first spermatocyte division. The part it plays in fertilization has not yet been determined, and so we have no definite ground upon which to base any theories concerning its function.

There is one thing, however, which I think stands out clearly and definitely as a result of even our limited knowledge of this element. The theory of the individuality of the chromosome must certainly receive a strong support from the behavior of this aberrant representative. Indeed, a more conclusive proof could hardly be imagined.

Concerning the name to be applied to this element, perhaps a little might be said. I am more firmly than ever convinced that it should be classed among the chromosomes, since it really is one and never anything else. Under no consideration, I believe, should it be placed with the ill-defined group of nuclear bodies included under the term "nucleoli." The real character of the chromosome cannot be ascertained until its office during fertilization and cleavage has been discovered; meanwhile the qualifying term "accessory" serves to distinguish this chromosome from all others, and is general enough not to predispose any one toward one conception or another while the solution of its character is in abeyance. The strictly chromatic nature of this element is recognized by Paulmier in his latest work (**26**), where he designates it as the "small chromosome." It is to be re-

gretted that, after having so far appreciated the character of the structure, he should confuse the nomenclature by applying the qualifying term "small" to it. The argument (**26**, p. 251) he so justly uses against the word "mitosome" applies with equal force in the present instance, and condemns the expression "small chromosome" as a misnomer, because, in most insects, this chromosome exceeds all the others in size. Accordingly, the preliminary term will be continued until a more fitting one is found.

IV.—COMPARISONS AND CONCLUSIONS.

With due regard to the importance of theoretical and comparative work, I hope to avoid what is certainly an error: the erection of a large superstructure of theory upon a small foundation of fact. Only the comparative study of numerous forms can serve as the basis for any far-reaching theories, and this, I believe, is yet to be accomplished. Since, however, the ground must first be cleared by weeding out the errors that unavoidably spring up in preliminary work of this kind, I venture to suggest instances wherein such mistakes appear to have been made by other investigators. In order to facilitate such a discussion, the generally accepted facts of the subject will be outlined in the beginning,

In the process of germ-cell formation in the male organism, there are three generally recognized stages. The first of these includes the changes by means of which the primordial germ cell, by rapid and repeated divisions, gives rise to a large number of cells, commonly called spermatogonia. These changes are included under what is usually termed the "division period." At its conclusion there are to be found in the sexual organ considerable numbers of cells which do not enter into division, but gradually increase in size during the early prophase of a long-delayed mitosis. These cells are then said to be passing through the "growth period." This prolonged existence in the prophase is an evident preparation for the unusual and characteristic divisions which follow. The essential features of these are the halving of the usual number of chromosomes, the production of others that are quadripartite in character, and the separation of these by two rapid divisions without an intervening resting stage. These fall within the "maturation period," so called. In the process of spermatogenesis, there follows a series of transformations, as a result of which the cells are converted into the highly specialized elements known as spermatozoa.

With these facts accepted, there remain to be determined the means by which the number of chromosomes is reduced, and the methods by which the tetrads are separated without entering into a

resting condition between two consecutive mitoses. These are the points which I wish to consider here.

Already the general methods of tetrad formation have been outlined. Now I wish to take up in a more detailed way the work done upon insect material.*

Wilcox (19), (20), (21), from a study of the "Spermatogenesis of *Caloptenus femur-rubrum*, and *Cicada tibicen*," concludes that the tetrads are formed by segmentation of the spireme thread into parts equal in number to the chromosomes of the spermatogonia. These subsequently unite by twos, and, by a concentration of the chromatic substance at the ends of the two rods, produce the tetrads. As each element of the tetrad is considered a chromosome, no form of division is possible except a cross-division separating whole chromosomes. This fact is recognized by Wilcox, when he states that, "According to my interpretation of the Vierergruppen in *Caloptenus*, the formula would be $\frac{a \mid b}{c \mid d}$. Both the divisions following the formation of a Vierergruppe would therefore be reduction divisions. . . . If my description of the ring formation be accurate, there may be two reductions."

I have examined numerous species of *Melanoplus*, including *femur-rubrum*, and I have never found anything to support the statements of Wilcox. I am convinced that he is mistaken in his view of tetrad formation.

His error arises principally in interpreting the segments formed from the spireme thread. In all the material that I have studied there exists an indisputable longitudinal splitting of the chromatic thread. This may be traced down through the rings and similar structures into the chromosomes themselves. This fact has escaped Wilcox's observation, for in his later paper (20) he reiterates his belief in the absence of any longitudinal division.

Having convinced himself of this fact, he proceeds to explain the origin of the tetrads by means of repeated cross-divisions of the

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*It has not been my purpose, in this paper, to carry a comparison of my results much beyond the work done upon insect material. I cannot, however, avoid a brief reference to the articles of some investigators where the conclusions agree so closely with my own. I would mention especially those of Moore (19) upon the Elasmobranch spermatogenesis, Griffin (25) upon *Thalassema* and *Zirphæa*, and Atkinson (24) upon *Arisæma* and *Trillium*. The close concordance of these results upon materials derived from so widely different forms speaks most strongly for the existence of a type form of division which, I believe, will be exemplified more and more widely as different species of animals and plants are studied.

The clear and accurate conclusions of Griffin receive so strong a confirmation from the appearances noted in *Hippiscus* as to make a reasonable doubt of their correctness almost impossible. Owing to the favorable character of the early prophase stages and the progressive changes of the different metaphase chromosomes in *Hippiscus*, any uncertainty that might have attached to Griffin's conclusions regarding the sequence of the longitudinal and cross-division is dispelled.

Besides these instances where the observer has clearly understood and definitely remarked the character of the maturation divisions, there are other cases where the figures presented by different authors would indicate the existence of a modified form of this type division, although their interpretations of them lead to different conclusions.

thread. In elaborating this conception, there is no denying that his diagrams are much more conclusive than are his figures.

The dumb-bells which he represents are nothing more nor less than the U-shaped figures so common to insect spermatogenesis. I am quite at a loss to reconcile his union, by pairs, of the chromatic segments with any real occurrences in the spermatocyte prophases.

Again, in his interpretation of the completed tetrad I consider Wilcox in error. I have never yet observed in Orthopteran material tetrads composed of spherical chromatids. In the Acrididæ, at least, they correspond in structure and method of division to those of *Hippiscus*. In a few of this author's figures, there are represented chromosomes in the metaphase of the first spermatocyte division which bear a general resemblance to those I have found in *Hippiscus*. Note, in connection with this point, Figs. 20, 22, and 25 (**20**). In Fig. 9, also, will be found a ring corresponding in structure to those represented in Figs. 15 and 15*a* of this paper.

In a previous article, I have already called attention to a correspondence between Wilcox's "nucleolus" and the body which I have described under the name "accessory chromosome." Further studies have confirmed me in my opinion that these bodies are identical structures. In fact, as observations multiply, the process of spermatogenesis in the insects seems to approach a type, the deviations from which are only in minor details, corresponding to variations in size and habit of the elements concerned.

In justice to Wilcox, however, I would say that the *femur-rubrum* material is far inferior to that furnished by *Hippiscus*, so that structures quite plainly apparent in the latter would be difficult to discern in the former. I believe that due importance should be attached to the character of the material employed by an investigator, so that statements based upon a study of favorable subjects, other things being equal, should receive credence over those resulting from a study upon less favorable observation material.

The latest paper by Paulmier (**26**) unfortunately reached me after the manuscript of this article was in the hands of the printers. On this account, I shall be unable to accord it the attention it deserves, and shall be obliged to confine myself to a few brief foot-notes. I hope, however, to consider it more at length in a subsequent paper.

In a recent paper (**11**) Paulmier discusses the formation and division of the tetrads in the spermatogenesis of the Hemiptera. It is gratifying to note that the processes in this order and in the Orthoptera appear to be essentially the same. So far as I know, Paulmier is the first to accurately describe the early changes taking place in the nuclear thread that result in the formation of the tetrad. These

are practically alike in *Anasa*, *Euchistus*, and *Hippiscus*. But if this parallelism extends throughout the process, as I am confident that it does, then Paulmier has fallen into error in his interpretation of the final stages and, with this, in the sequence of the longitudinal and cross cleavages.

I believe it will be found that he has overlooked the movements of the chromatids in the metaphase of the first spermatocyte division. I would call attention to the striking resemblance between his Fig. 12 and Fig. 22*e* of this paper. This would seem to indicate the identical character of these two chromosomes, and I think further study will confirm this belief. I would, therefore, suggest that Paulmier is mistaken in considering that the first division is a cross and the second a longitudinal. The reverse of this, I think, I have shown to be the case.

Mention has already been made of the nomenclature employed by Montgomery (**8**) in considering the phases of cell division. I wish here to protest against his use of well-established terms in other senses than those intended by their originators. It is with difficulty, from Montgomery's description, that one can trace out the cycles of changes undergone by cells during division.

In discussing the first spermatocyte, he commences with the "anaphase." The term "anaphase" was first used by Strasburger in 1884 to designate that phase of indirect cell division during which the chromosomes are transported from the equatorial plate to the poles of the cell and there transformed into the diffuse chromatin of the resting nucleus. By the introduction of the term "telophase" (which is also employed by Montgomery), the anaphase is made to include only the changes involved in the transportation of the chromatin elements from the equator to the poles of the cell. If, therefore, it is used by Montgomery in its proper sense, it would be the anaphase of the spermatogonia, and not of the spermatocyte, that is described. If not thus used, then it is misapplied with a new meaning. Such appears to be the case.

Three sub-phases are mentioned by Montgomery as occurring under the anaphases. These are the "early anaphase," the "synapsis," and the "post-synapsis." Since the "early anaphase" witnesses the formation of a nuclear membrane around the groups of chromosomes arising from the last spermatogonial division, it must correspond to the true telophase, for, according to Heidenhain, this is the period during which the daughter nuclei are supplied with membranes and during which the nuclei are reconstructed. Montgomery's early anaphase is, therefore, the telophase of the spermatogonia.

It is a difficult matter to locate the "synapsis." Moore, who coined

the term "synaptic phase," intended it to designate that period of the *prophase* during which a fusion of the chromosomes existing in the spireme takes place in such a way that half the normal number arises from its subsequent division. Since it is at this time that the concentration of the chromatin at one side of the nucleus takes place, under some conditions, the term "synapsis" has come to apply to this massing of the chromatin. Montgomery attaches the term to a condition of the *telophase* in which the still persisting chromosomes are collected at one side of the nuclear cavity. It is generally understood that synapsis does not occur except during the spireme condition of the nucleus. This is expressed by Häcker (4) in the following language: "**Mit dem von Moore stammenden Ausdruck 'synapsis'** bezeichnet man neuerdings vielfach ein Stadium der Mutterzellkerne, in welchem der in der Regel shon längsgespaltene, aber wahrscheinlich noch unsegmentierte, Chromatinfaden auf einer Seite des Kernraums, gewöhnlich im Umkreis des Nucleolus, einseitig kontrahiert erscheint."

While dwelling upon the subject of "synapsis," I should like to state that I consider the appearance itself to be an artefact. Doubtless Moore and Häcker are correct in their belief that the nucleus is in a peculiar condition at the time when the contraction phenomenon occurs, but that the chromatin exists in the living cell in the form of a concentrated mass, I very much doubt. My study upon insect spermatocytes leads me to this belief, for the following reasons: In properly treated material no synapsis occurs. When observed, its artificial character is evident because the mass of chromatin is always to be found in the region of the nucleus opposite to the point at which the fixing or dehydrating fluids had free entrance. Thus, in a freely exposed follicle, the chromatin masses always lie toward the central axis of the follicle.

Montgomery follows his synapsis phase by the post-synapsis, in which the mass of chromosomes becomes disentangled, and the liberated elements lie free on the periphery of the nuclear vesicle. Its termination yet witnesses no dissolution of the spermatogonial chromosomes and formation of a spireme thread from their substance. I am not prepared to criticize these views concerning the Hemipteran cells at this time, but in the Orthoptera I am sure no such occurrences are to be found. In these, the spermatogonial chromosomes, with the exception of one, rapidly disintegrate, and from their scattered granules a very fine spireme thread is formed. In *Hippiscus*, since the spermatocytes pass through the winter in this spireme stage, any synapsis, if it occurred, would easily be found in the long follicles filled with the prophase spiremes in various stages of advancement.

The telophase, according to Montgomery, is the "stage between the post-synapsis of the anaphase and the rest stage." The term "telophase" was coined by Heidenhain in 1894 to designate that period of cell division during which the chromatin framework of the daughter nuclei is produced from the chromosomes of the preceding generation and during which the cells are separated from each other by a cell wall. Such is not Montgomery's conception, for his subsequent "rest" stage is one in which a diffused chromatic thread exists, and from which the chromosomes of the first division are formed by segmentation. The "telophase" and "rest," so far as I can discover from the text and drawings, are merely early prophases of the spermatocyte. In Orthopteran material, there is no true rest stage of the nucleus between the spermatogonia and the spermatocytes. The chromatin passes rapidly into a fine spireme condition from the spermatogonial chromosomes by dispersion and rearrangement of their substance.

The prophase of Montgomery appears to be in reality a late prophase. The chromatin, it is stated, exists in the form of a number of threads, each of which is termed a chromosome. These are less in number than the bodies which subsequently divide in the metaphase. They should not, therefore, be termed chromosomes, for the same reason that we do not call the single chromatic thread of the early prophase a chromosome. In the prophase, it seems to me, there can be neither more nor less chromosomes than are formed in the metaphase before division.

In his earlier paper Montgomery was positive in his statement that there is no longitudinal division of the spireme. In a correction (9) appearing later, however, he frankly acknowledges his mistake in this, and states that his first conception of two transverse divisions is verified by occasional instances. I am very much inclined to doubt any departure from the typical chromosome division in any of the cells that form functional sexual elements. I believe that in favorable material the type division will be found exemplified in every normal mitosis. The mere occurrence of the chromosomes, with their longer axis parallel to the spindle and a constriction in the equatorial plate, would be no reason whatever for assuming that the division following is to be a transverse one. This is apparent from a study of the chromosomes in the metaphase of the first spermatocytes, such as those of *Hippiscus*. In commenting upon Paulmier's belief that the first division is a cross-division, with which Montgomery agrees, I have stated my reasons for believing that such a conclusion is wrong; I shall not therefore repeat them here. In confirmation of my belief that the chromosomes of the first spermatocyte are essentially the same in all insect material, I would ask a comparison of the

central chromosomes of Fig. 145 by Montgomery and Fig. 15*a* of this paper.

It affords me great pleasure, after having had to differ so much from Montgomery in other matters, to confirm his belief in the origin of the accessory chromosome. As already described, it arises in *Hippiscus* and other Acrididæ, as it does in *Euchistus*, from one of the spermatogonial chromosomes which does not become reticulated and joined with the substance of the others to form the spireme. In the Locustidæ, as previously stated, I have not been able to satisfy myself that the element has just this origin. On the other hand, I have no proof that it does not thus arise. Further comparative study, now begun, will doubtless make this point clear.

I have already stated that my studies upon insect spermatogenesis have led me to believe that the processes of spermatocyte divisions are essentially the same throughout the class Insecta. I must, therefore, disagree with the conclusions reached by Henking (5) from a study upon *Pyrrhocoris apterus*. According to this author, the twenty-four chromosomes, characteristic of the spermatogonia, appear in the first spermatocyte, but, instead of being single, are united by pairs. The result of this is that an equatorial view of a spermatogonial metaphase will show a plate of simple, round chromosomes (twenty-four in number from a polar view); while, on the contrary, a chromatic plate of the first spermatocyte shows the chromosomes to be dumb-bell shape, and arranged as a double plate, which, viewed from the pole, exhibits twelve chromosomes.

In reaching this conclusion, Henking disregards, or rather misinterprets, certain significant figures of the late prophases. I refer to those represented in his Fig. 20, which he mentions as "die mit vier Verdickungen versehenen Ringe." Instead of considering these normal structures, he regards them as transformation stages, or accidental unions, of simpler elements.

Henking's error consists in regarding the elements of the first spermatocyte division as double instead of quadruple—a mistake which would easily be made if the fully formed structures were examined instead of those in the preliminary stages. The true difficulty is recognized by vom Rath when he says: "Ich erinnere daran, dass auch bei *Gryllotalpa* bei den beiden letzten Theilungen stets 2 Chromosomen einander genähert sind und ein Paar bilden, bei *Pyrrhocoris* könnte eine noch weiter gehende Vereinigung eines Chromosomen-Paares bis zu einer scheinbaren Verschmelzung stattgefunden haben." As in *Hippiscus*, the chromatids are closely united, so that the lines of separation are quite invisible. Particularly would this be true of cells where the elements are so small as they

are in *Pyrrhocoris*. Undoubtedly the elements of the first spermatocytes of *Pyrrhocoris*, like those of other insects, are quadripartite —for the early stages of their formation clearly indicate this. We have here another example of the fact that it is to the formative stages of the chromosomes that we must look for indications of their structure, rather than to the mature elements themselves.

The material derived from *Pyrrhocoris* is well adapted for the solution of many cytological problems, but I maintain that the structure and divisions of the chromosomes are not one of these. Surely material which requires such reasoning as Henking employed in the following quotation is not of the most desirable character. He says: "Dennoch bin ich der Meinung, dass die hier vorliegende Theilung theoretisch einer Längstheilung gleichzusetzen sei; denn wo gestreckte Chromosomen vorhanden sind, pflegen sie den Polen nicht ihre Enden, sondern ihre Seiten zuzukehren und also der Länge nach getheilt zu werden. Warum sollten wir hier etwas Anderes annehmen?"

In the germ cells of animals and plants there are wide variations in size, form and manner of division of the chromosomes, but I believe the underlying structural principle will be found the same in all, when the details are thoroughly worked out. Thus, for instance, the chromosomes of *Pyrrochoris* and *Hippiscus* differ remarkably in almost all points, if the elements in the metaphase of the first spermatocyte are considered. If, however, we look back to the prophases, the quadripartite nature of each is apparent.

Too much importance cannot be laid upon the necessity for a thorough understanding of the early formative periods in the history of the first spermatocyte chromosomes. The remarkable feature about the maturation divisions is not, it seems to me, the separation of the chromatids, but rather the means by which they are associated in preparation for these divisions. Therefore, objects which present these early stages to the best advantage are the ones which are most likely to give us a proper understanding of tetrad formation and division. Insect material seems to be especially favorable for this purpose, particularly that derived from the Orthoptera and Hemiptera.

Henking, with others, assumes that because there are twenty-four chromosomes in the spermatogonia and twelve double ones in the first spermatocyte, the latter represent the ones of the earlier generation united end to end. I believe that there is lacking a sufficient proof of this assumption. In this connection, I would call attention to the great difference that exists in the prophases of these germ cells and those of the body cell. In *Hippiscus*, the chromatin passes the winter in the form of the spireme, as it does also in other animals and

some plants, and is thus long established in relations that differ from the ordinary resting nucleus. Because this spireme in the spring divides into half the number of segments that the spermatogonial spireme did, are we justified in assuming that each of these segments represents two longitudinally arranged chromosomes of the early cell generation? It would appear that, with our present knowledge of the subject, we are not; and certainly it would be less prejudicial to an impartial study if this fact were made clear in discussions upon the question.

Under the term "nucleolus," Henking discusses a structure which appears to be identical with that which I have termed the accessory chromosome. I am led to this belief by the statements he makes concerning the constancy of staining power, position in the nucleus, and regularity of outline. In all these features there is a striking resemblance between the elements. Regarding these points he says: "Erscheint der Nucleolus der jüngsten Hodenzellen bei der genannten Methode farblos, so nimmt er nun begierig Farbe auf, ein Verhalten, welches ganz regelmässig ist. . . . Allein der Nucleolus hat bei den Veränderungen von Kern und Zelle sein Aussehen nicht gewechselt. . . . Der Nucleolus behält seine Kugelgestalt unverändert bei, während die Chromosomen gewissermassen Pseudopodien aussenden und sich so zu einem Netz vereinigen. Der Nucleolus bietet seinerseits den Pseudopodien keine Ansatzflächen und bleibt daher isoliert."

Later, in discussing the chromosomes, he mentions peculiarities, one of which puts it in agreement with the later changes undergone by the accessory chromosome in Orthopteran cells. These points are, again, the size, staining intensity, and smooth contour. It is asserted with great positiveness that, in the last division of the spermatocytes, this element goes over undivided into one of the daughter cells. Certain appearances in the testicular cells of *Xiphidium* at one time led me to believe that the accessory chromosome was thus apportioned by the last spermatocyte division. I am not now prepared to make a positive assertion upon this point, but I hope by the aid of more favorable material to reach a conclusion concerning the matter. Be this as it may, there is an evident resemblance between Henking's undivided chromosome in *Pyrrhocoris* and the accessory chromosome of *Xiphidum*. In view of all these resemblances, I do not doubt that the accessory chromosome has been observed by Henking.

The observations of vom Rath (**14**) upon the spermatocyte divisions of *Gryllotalpa vulgaris* give us an excellent idea of the actual division of the chromosomes. The exact origin of these tetrad elements, however, is not clearly demonstrated. As a result of this, each of the

chromatids is denominated a chromosome. The objection to this designation has already been stated in the criticism upon the work of Wilcox.

Vom Rath's criterion of valence is based, not upon the origin of the elements, but rather upon their relation to each other. In deciding as to whether or not the tetrad itself shall be called a chromosome, he makes use of the following reasoning: "Mit grösster Aufmerksamkeit habe ich die Verbindungsfäden zwischen je 4 Chromosomen studiert, aber niemals eine Spur vom chromatischer Substanz wahrgenommen, so dass die 4 Chromosomen jeder Gruppe als Einzelchromosomen und nicht die Gruppen selbst als Einheiten aufgefasst werden müssen." Just why the presence or absence of chromatic connection should determine the nature of a chromosome I cannot see. Suppose, for instance, that the chromatids of a tetrad in *Gryllotalpa* were so closely approximated that they came in contact with each other: would this in any way alter the character of the elements with respect to their origin and ultimate fate?

Again, in *Hippiscus* the chromatids constituting the tetrads are so closely united that their lines of contact are almost invisible. Suppose, now, that these were so disposed that they were brought in contact only by the interposition of linin threads: would this in any way change the essential character of these elements? There seems to be no reason for believing that it would. The various families of insects have their characteristic habits in the formation of the tetrads, but they are, in all, essentially the same structure, and should not be differently designated on account of these peculiarities.

Concerning the facts recorded by vom Rath in his paper I find few with which to disagree. The main contention I have to make is with regard to the statement concerning which of the divisions corresponds to the original longitudinal splitting of the thread. It is his evident opinion that the second division completes the separation already inaugurated in the prophase. He says in this connection: ". . . Es kann folglich die eine der beiden Trennungen der Chromosomen auf diese vorzeitige Spaltung des Chromatinfadens zurückgeführt werden, ob dies nun aber die erste oder die zweite Theilung ist, kann nach den Präparaten nicht mit Sicherheit entschieden werden, ich mächte eher an die zweite Theilung denken." As in the case of *Pyrrhocoris*, the evidence presented by the elements during their prophase condition is not conclusive, or, if so, has not been given its true importance. In all respects, the spermatogenesis of *Gryllotalpa* appears to conform to the typical insect plan. There is no mention made, however, of the occurrence of any such element as the accessory chromosome. I have not had

the opportunity to study this object, but other members of the Gryllidæ which I have examined present this element very much as it appears in the Locustidæ, and so I have no doubt that it also occurs in *Gryllotalpa.*

The work of Toyama (16) upon the spermatogenesis of the silkworm is not of a character to throw much light upon the methods of chromosome division. His figures would indicate that the chromatic elements are exceedingly small—so minute, indeed, as to be practically worthless as a means of determining chromosome structure.

It is stated, however, that the germ mother cell contains twenty-eight chromosomes, and that in the first mitosis these divide transversely and transmit to each of the daughter cells the same number of chromatic elements. There is, as yet, no reduction in number of the chromosomes, but in the mitosis of the second spermatocyte this is brought about by one-half of the chromosomes going into each of the resulting cells. The mitosis of the second spermatocyte is, therefore, not a division of chromatic elements, but a mere sifting apart.

I should consider such a process as this extremely improbable and, in view of the results obtained upon insect material better adapted for the observation of such points, unworthy of credence unless well supported by more undoubted cases. The regrettable habit of terming all chromatic elements chromosomes is exemplified by this author and leads to much confusion in determining the nature of the structure he is discussing.

There is some reason to believe that the body termed "nucleolus" by Toyama is the accessory chromosome of other insect cells, although the facts given are not sufficient to warrant a positive statement that such is the case.

V.—SUMMARY.

1. As a result of the last spermatogonial division, the much reduced daughter cells are each provided with the somatic number of chromosomes. All but one of these rapidly disintegrate and from their substance produce the spireme of the first spermatocyte. One persists in its original form and, assuming a peripheral position, continues to stain as does a chromosome of the metaphase. During metakinesis it is divided like the other chromosomes. This is the accessory chromosome.

2. There is no true resting stage between the spermatogonia and spermatocyte. The prophase spireme of the spermatocyte is formed immediately from the chromosomes of the spermatogonia by a dispersion and rearrangement of their substance. The resulting thread persists throughout the winter and segments into chromosomes only at

the approach of warm weather. Late stages of the spireme show unmistakable evidences of a longitudinal cleft.

3. The segments of the chromatic thread offer clear and convincing evidence that the resulting chromosomes are quadrivalent structures. They may exist in the form of rods, double-V figures, or rings, but all are modifications of one type. In this the segment is split longitudinally, and again in the center at right angles to the first cleft. The members of this compound unit are able to move upon each other so as to produce cross-figures with arms of various proportionate lengths.

4. A concentration of the loose elements of the prophase produces the mature chromosomes of the first spermatocyte metaphase. This, from the method of its production, is known to be quadrivalent, although planes of division are usually indistinguishable. In the equatorial plate, the chromosomes arrange themselves with their longer axis at right angles to the spindle. Fibers attach to the chromosomes at their middle point, which corresponds to the place where the cross-division was previously noted.

5. By contraction of the fibers, the elements of the tetrad are removed from each other in pairs. Separation takes place along the plane corresponding to the original longitudinal cleft, but without divergence of the chromatids. In this way the chromosome in the final stage of separation resembles the one just beginning to divide, except that its longer axis is parallel to the spindle axis. Movements of all the chromosomes in a nucleus are not coincident, so that the various stages may be noted in the same cell.

6. The balance of forces inherent in the tetrad chromosomes appears to be destroyed when the diads separate, for the chromatids composing these bipartite elements immediately diverge when they lose connection with their sister pairs. They thus travel to the poles in the form of a V-shaped structure more or less closely united at the apex. During the telophase they become closely aggregated but never lose their identity. There is, accordingly, no intermediate rest stage.

7. The second spermatocyte division figure is established almost as soon as the daughter cells are separated by the growth of an interposing wall. In it, the spindle is small, and the chromosomes are arranged on its periphery in such a way that the chromatids of each pair are superimposed in the plane of the spindle axis. Fibers attach at the same place they did in the first spermatocyte and easily separate the loosely joined chromatids. These move apart to the poles and coincidentally the cell and spindle increase in length. Since the fibers of the first spermatocyte figure were attached to the chromatids at a point marking the plane of cross cleavage, the second spermatocyte mitosis which separates them at this point is a cross-division.

With the ingrowth of a cell wall, the second spermatocytes separate and produce the spermatids, and these transform directly into spermatozoa.

8. The sequence of the longitudinal and cross-divisions appears to be constant. There is reason to believe that it is of fundamental importance, and, therefore, accounts of the indiscriminate occurrence of both forms in the same cell generation should be accepted with caution. If the polar body of the parthenogenetic egg acquires new properties by its brief separation from the egg which it subsequently fertilizes, there is every reason to suppose that the order of chromatid separation in the forming spermatozoa is vital and essential.

9. The accessory chromosome is a constant and important element of the germ cell. It arises, in the Acrididæ, from a spermatogonial chromosome, and from that time forward maintains a separate and distinct existence. During the prophases, when occur the profound changes that result in the production of a nucleus with only half the number of ordinary chromosomes, this structure stands aloof and self-contained. With the establishment of the mitotic figure of the first spermatocyte, however, it takes its place with the other chromatic elements and becomes indistinguishable from them henceforth until the spermatids are formed. Here it again becomes distinct and conspicuous.

10. All the phenomena incident to the formation of the male germinal elements in the Acrididæ speak for the existence and prevalence of a typical series of processes through which all elements pass on their way to the production of the functional spermatozoon.

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PLATE XV.

All drawings were made under the camera lucida, with an optical combination consisting of a Zeiss 2 mm. apochromatic objective and compensating ocular No. 8. This produced, at the drawing surface, a magnification of 1000 diameters. In the photomechanical reproduction of the drawings this has been reduced to 750 diameters.

Fig. 1.—A semi-diagrammatic view of a late spermatogonial anaphase, showing the number, position and arrangement of the chromosomes.

Fig. 2.—Same as fig. 1.

Fig. 3.—Telophase of the last spermatogonial division, showing the small size of the cell, and an early stage in the loosening of the chromatic structures.

Fig. 4.—Very early prophase of the spermatocyte, in which is shown the production of granular chromatin from the chromosomes of the spermatogonia. Portions of the disintegrating chromosomes shown at *a*. At *b* appears one which does not lose its identity; this is the accessory chromosome.

Fig. 5.—A somewhat later prophase, in which the chromatic thread is established. The accessory chromosome has become definitely specialized and has taken its characteristic peripheral position.

Fig. 6.—A still later prophase, in which the chromatin thread is shown very much contorted. At this stage it evidently consists of many pieces. The accessory chromosome is viewed from the side.

Fig. 7.—A stage of the prophases in which the chromatin has become aggregated into a single thread. The accessory chromosome is here exhibited in cross-section.

Fig. 8.—At this stage the single thread has become divided transversely into a number of segments. Each of these, later, forms one of the elements which is found in the metaphase of the primary spermatocyte.

Fig. 9.—About the same stage as fig. 8, but showing the accessory chromosome.

Fig. 10.—This represents a prophase stage closely following that shown in figs. 8 and 9. Here, however, the chromatic segments have separated, taken a peripheral position, and become finely granular. They have, as yet, assumed no particular form.

Fig. 11.—In this the chromatic segments are represented in their characteristic loop form. The series of figures from 1 to 11 was drawn from cells in a single follicle, and, therefore, represents progressive development. The gradual and regular increase in size of the nucleus and cell, from the stage represented in fig. 3 to that in fig. 9, is very noticeable.

Fig. 12.—Here is represented the early longitudinal division of the chromatic segments. In many cells it appears in a much more pronounced manner than is indicated.

Fig. 13.—A cell at about the same stage as that regresented in fig. 11. This indicates the great variation which the segments of the chromatic thread may undergo.

Fig. 14.—Fragment of a cell, showing a portion of the nuclear elements. These are all seen to be longitudinally divided. One of them is also bent at the center where the cross-division of the second spermatocyte is to occur. The quadrivalent character of the element is thus clearly indicated. By the subsequent concentration of the chromatic material these lines of division become indistinguishable.

Fig. 15.—The stage here represented follows closely upon that of the preceding figure. Two of the elements yet show their quadripartite nature. The one in the center of the nucleus has bent upon itself until the free ends have united to form a ring.

Fig. 15*a*.—A somewhat later stage than fig. 15, showing a greater concentration of the chromatic elements. The longitudinal and cross-divisions are, however, still plainly visible. At one side of the nucleus the astral rays are beginning to develop.

Fig. 16.—A cell of the same age as that shown in fig. 15, but with the nuclear elements of a more granular character and with no indication of division.

Fig. 17.—This cell represents a stage a trifle in advance of that shown in figs. 15 and 16. The nuclear element just below the accessory chromosome clearly presents the evidences of both longitudinal and cross-division. It will be noticed that the chromatids are in contact along the plane of cross-division for almost as great a portion of their length as they are along the plane of the longitudinal division. This is a significant indication of future movements of the elements.

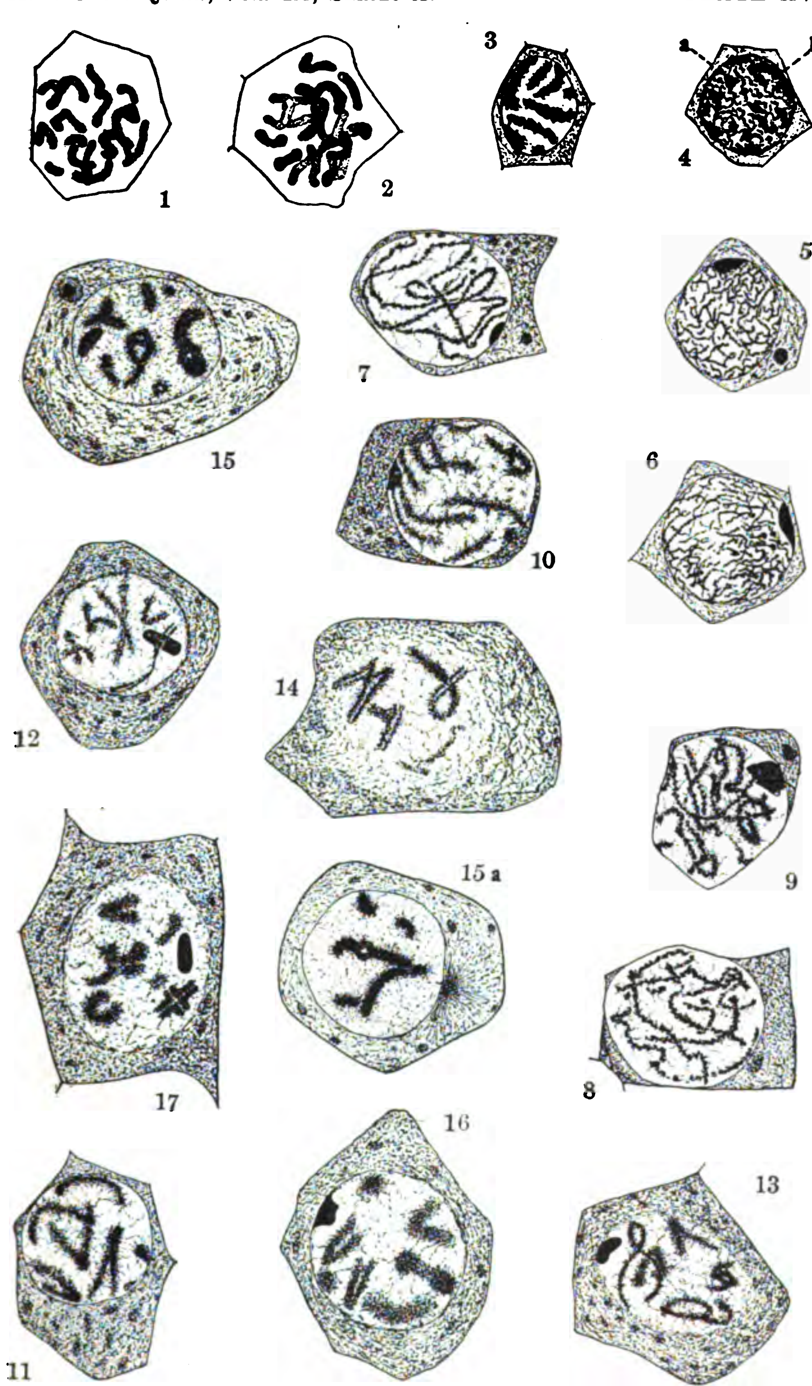

1
2
3
a
b
4
5
15
7
10
6
12
14
9
17
15 a
8
16
13
11

PLATE XVI.

Fig. 18.—A metaphase of the first spermatocyte mitosis. This figure shows the various forms assumed by the chromosomes during their division.

Fig. 19.—Same as fig. 18.

Fig. 20.—One side of the cell, exhibiting a portion of a spindle and the chromosomes. These are in different stages of division, the central ones being nearly separated.

Fig. 21.—Mid-anaphase of the first spermatocyte. Immediately upon the separation of the chromatids along the plane of the longitudinal cleavage, the two remaining chromatids spring apart at the ends unconnected with the fibers, as is here represented.

Fig. 22.—A series of figures, drawn with the camera lucida, showing the changes experienced by the chromosomes during the first spermatocyte division. The progressive movement of the chromatids along the invisible plane of cleavage is here conclusively shown; *a*, *b*, *c*, *d* and *e* were drawn from one cell, and indicate clearly the position of the chromosome with reference to the spindle; *h* shows the form of chromosome, of the stage represented by *a*, when viewed from the pole, and *i* is a ring formed by the union of the free ends of the chromatids seen in *h*.

Fig. 23.—Telophase of the first spermatocyte division, exhibiting the close massing of the chromosomes. The persistent character of the spindle fibers is here indicated.

Fig. 24.—Metaphase of the second spermatocyte. The bipartite structure of the chromosomes, first noticed in the anaphase of the first spermatocyte (21), is here clearly indicated. It will be noticed that in this stage the spindle is much shorter than that of the first spermatocyte metaphase.

Fig. 25.—Another cell of the same character as shown in fig. 24. Note the persisting spindle fibers of the first spermatocyte division at one side of the mitotic figure.

Fig. 26.—Anaphase of the second spermatocyte division. The individual chromatids are here seen, differing much in their form from that of the paired elements found in the anaphase of the first spermatocyte division. In this particular cell each stands nearly opposite the sister element to which it was united. Note the elongated form of the spindle.

Fig. 27.—A somewhat later anaphase, in which is to be observed the concentration of the archoplasmic substance at the periphery of the spindle, and also the variation in the form of the chromatids.

Fig. 28.—Polar view of a second spermatocyte anaphase, showing the chromatids moving to the poles.

19

18

20

a

b

c

22

d

e

f

21

23

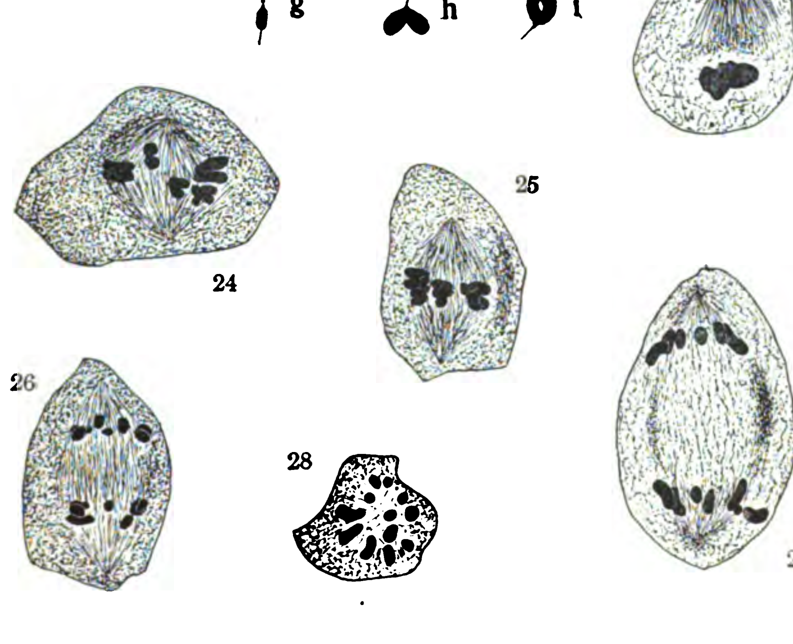


PLATE XVII.

These plates were made with a Zeiss 2 mm. apochromatic objective, arc light illumination, at an original magnification of 1000 diameters. In reproduction, this has been reduced to 750 diameters, and so corresponds to that of the drawings.

Fig. A.—This represents the metaphase and anaphase of spermatogonial divisions. So rapid are these cycles in their succession that the continuity of the archoplasmic substance between the centers of the previous generation is not lost. This simulates the "antipodal cone" of Boveri very closely.

Fig. B.—The cells on the left of the spermatocyst wall are in the telophase of the last spermatogonial division. Cf. fig. 3. To the right of the wall are very early prophases of the spermatocytes. Somewhat earlier than fig. 4.

Fig. C.—Later first spermatocyte prophase, showing the character of the chromatin segments and the linin connecting threads. Near the upper edge of the figure is seen the accessory chromosome, marked by the smoothness of its outline and the homogeneous, transparent structure.

Fig. D.—In this figure is shown a chromatin segment with the central cleft indicated in figs. 14, 15, 15*a*, and 17.

Fig. E.—A segment as in D, accompanied by a ring showing the same structure. Note the archoplasmic radiations proceeding from a center located on the nuclear membrane, as shown in fig. 15*a*.

Fig. F.—In the upper part of the figure is exhibited a first spermatocyte in the metaphase condition as viewed from the side. Chromosomes are seen in different stages of division. The cell below presents the form of the elements in the same stage when observed from the pole.

Fig. G.—Two spermatocytes in the metaphase of division. Chromosomes in various stages of separation shown. A central opening visible in the element at the left of the figure.

Fig. H.—Here are shown chromosomes in the form of loops and rings, with the chromatin drawn out into a long thread by the contracting fibers attached to them. Cf. figs. 22*h* and 22*i*.

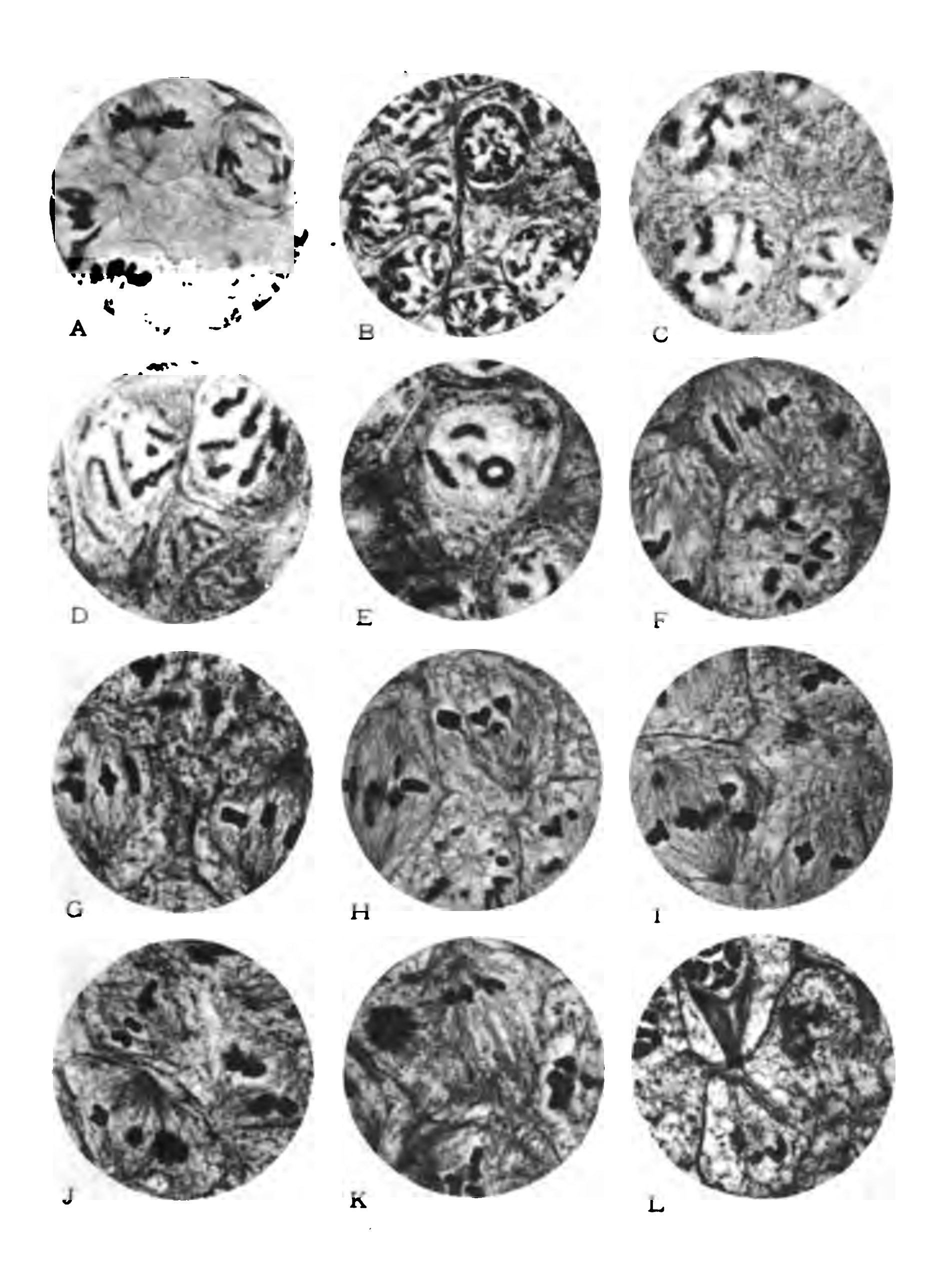
Fig. I.—Another first spermatocyte metaphase in which are chromosomes at about the middle stage of their separation. Cf. figs. 20, 22*b*, and 22*c*.

Fig. J.—Second spermatocyte metaphases. The radially disposed diads with the chromatids superimposed in the plane of the spindle shown. Cf. figs. 24 and 25.

Fig. K.—An anaphase of the first spermatocyte, showing the diads near one pole of the spindle. At the left a polar view of a trifle later stage.

Fig. L.—Telophase of the first spermatocyte, in which are seen the ragged outline of the chromosomes and the persistent spindle fibers between the daughter cells. Somewhat earlier than fig. 23.

(Drawings and photomicrographs by the author.)


A
B
C
D
E
F
G
H
I
J
K
L

THE

KANSAS UNIVERSITY QUARTERLY.

(VOL. IX, NO. 2.—APRIL, 1900.)

SERIES A.—SCIENCE AND MATHEMATICS.

CONTENTS:

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KANSAS UNIVERSITY QUARTERLY.

VOL. 9, NO. 2. APRIL, 1900. SERIES A.

COCCIDÆ OF KANSAS, III.

Contribution from the Entomological Laboratory No. 72.

BY S. J. HUNTER.

With Plates XVIII to XXIV, inclusive.

Chionaspis ortholobis Comstock. Plate XVIII, figs. 1, 2.

On willow (*Salix* sp.) on bank of Kaw river, and cottonwood (*Populus* sp.) in the vicinity of Lawrence; also on willow (*Salix*) on University campus.

Chionaspis salicis-nigræ Walsh. Plate XIX, fig. 1.

On willow (*Salix* sp.) near Lost Springs, Marion county, and on host of same genus near Greeley, Anderson county.

In my study of these two species I have found the differentiation (when the mature female only was represented in the material at hand) attended by some uncertainty. In looking over the literature I find the same difficulty sometimes expressed. The distinctive characteristics of each I have endeavored to set forth. The comparisons are based upon an abundance of material determined by the writer from the Kansas localities given, and upon the following from the Division of Entomology at Washington: Specimens of *C. ortholobis* from San Bernardino, Cal., the type locality, and *C. salicis-nigræ* from Mankato, Kan., authentic material, which through the courtesy of Mr. C. L. Marlatt I have had the privilege of studying in this connection.

C. ortholobis.	*C. salicis-nigræ.*
SCALE OF MALE.	
Without carinæ.	Tricarinate.
Exuviæ dark yellow or brownish.	Exuviæ pale lemon yellow or colorless.
SCALE OF FEMALE.	
White.	White.
1.8–2.2 mm. long.	2.6–3.4 mm. long.
Exuviæ yellowish brown.	Yellow or colorless.

PYGIDIUM OF FEMALE.

Median lobes almost fused in basal half; inner margins frequently divergent in distal half, serrate.	Median lobes short, broad, symmetrically rounded at tips.
Second lobes half or less than half as long as median lobes.	Second lobes half or more than half as long as median lobes.
Space between second and third lobes less than twice the distance between the first and second lobes.	Space between second and third lobes more than twice distance between first and second lobes.
Third lobe, inner lobule less than one-half inner lobule of second lobe.	Third lobe frequently prominent; inner lobule = one-half inner lobule of second lobe.[1]
Plates 1, 1–2, 1–2, 1–2, 1–4.	Plates 1, 1–2, 1–2, 1–2, 1–5.
Circumgenital glands: Median, 17–24; post. lat., 14–27; ant. lat., 21–33.	Median, 23–30; ant. lat., 17–53; post. lat., 19–40.
In second row dorsal glands, posterior group absent.	Posteriors 1–4.
Anteriors 2–6; minute circular glands absent.	Anteriors 2–4; minute circular glands 1–10.

Chionaspis salicis-nigræ, readily separated from *C. ortholobis* by its male scale, can, from observations made upon the pygidia of fifty-four females, be said to differ in this structure by its shorter and broader lobes, by its possession of the posterior group of dorsal glands in the second row, and the presence of minute circular glands most abundant in the anterior group, second row, and visible beneath (ventral aspect) the circumgenital glands. In an examination of twenty-seven mounts of *ortholobis* and twenty-seven mounts of *salicis-nigræ*, I found this posterior group in second-row dorsal glands absent in all *ortholobis*, and present in all but one *salicis-nigræ*; this individual *salicis-nigræ* was well marked with the minute circular dorsal glands. The statement of Comstock[2] concerning median lobes of *ortholobis*, "mesal margins are parallel for more than half their length," holds good in many individuals among *salicis-nigræ*. "The distal margin of each (*ortholobis*) is rounded"[2] does not always obtain, since the inner distal margin is frequently divergent while the outer margin is rounded.

Chionaspis americana Johnson. Plate XIX, fig. 2.

Scale of female, 2 to 3.5 mm. in length; exuviæ 0.8 mm. long, sides diverging; generally straight, sometimes curved to right or left, curved scales located singly, broadly convex, dirty white.

Scale of male, tricarinate, 0.7 to 1 mm. in length, sides nearly parallel, clear white; exuviæ pale lemon yellow.

Mature female. The pygidium bears three pairs of lobes. Median lobes prominent, fused almost entire length of inner margins, sloping rapidly laterad, lateral margins with from one to three distinct

1. Cooley says "third pair often almost obsolete." Sp. Bull. Hatch Exp. Sta. Aug. 1899, p. 19. When this is the case lobes 1 and 2 are proportionately depressed.

2. Rept. U. S. Comm'r Agr. 1880, p. 317.

notches. Second lobes prominent, consisting of a large mesially inclined inner lobule, showing one or two marginal notches, and a shorter, more erect, outer lobule, sometimes with one notch. Third lobe generally compressed, though clearly distinguishable, division into two lobules apparent, inner lobule generally entire, margin of outer lobule notched once or twice, spines appear singly, as shown in figure 2, plate XIX, and grouped, beginning laterad of the median lobes, as follows: 1, 1–3, 1–2, 2–4, 4–8. The circumgenital glands range in number: Median groups, 16–26, anterio-laterals, 15–36, posterio-laterals, 15–39. Of the thirteen specimens in which the glands were counted, ten had decidedly more glands upon the right side than upon the left side. Location and number of the dorsal glands shown in the figure.

Male. The author of this species, Prof. W. G. Johnson, records two forms of males—"A perfect male with fully developed wings, and a pseudo-imago with rudimentary wings."[3]

This species is very common in Lawrence and vicinity, where I have taken it chiefly upon the outer branches of the white elm, but have also found it existing upon the trunk of the tree. I have received it from Floral, Cowley county, and Abilene, Dickinson county, upon badly infested twigs of the white elm.

In the abundant material studied, from five localities in Douglas county, and at Abilene and Floral, little striking variation is to be noted. The plates are sometimes forked and sometimes simple, the limits of circumgenital glands rather large; lobular crenulations appear at irregular intervals. The structural characteristics of the species in this latitude, however, appear to be fairly constant.

Chionaspis platani Cooley. Plate XX, fig. 1.

Scale of male, 0.9 to 1.3 mm. in length, sides parallel, diverging, slightly oval, without carinæ, exuviae lemon yellow, occupying about one-fourth the length of scale.

Scale of female, 1.4 to 2 mm. in length, broadens posteriorly sometimes abruptly, color favors the whitish coloring of the bark of host, sometimes obscured by the characteristic pruinose coloring of the bark; exuviæ dark reddish brown, prominent, about one-fourth of length of scale; little or no ventral scale.

Female. Pygidium bears three pairs of lobes; median lobes prominent, divergent from inner base, plainly serrate; second lobes consist of two lobules, the inner lobe the more prominent, the outer lobe extending but little if any beyond the marginal outline, faintly serrate; the third pair obscure, inner lobule noticeable, the outer represented are arranged laterad of median lobes, beginning at the median lobe 1,

3. Bull. Ill. St. Lab., vol. IV, p. 391.

generally as a bench-like lateral extension of the inner lobule. Plates 1, 1–2, 1–2, plates simple, spines and dorsal glands arranged as shown in figure, together with an average number of circumgenital glands.

Since this scale is described from Kansas, the specimens in hand conform with Cooley's description. The male scale seems to be uniformly larger than in the type insect, and with darker exuviæ.

Chionaspis pinifoliæ Fitch. Plate XX, figs. 1, 2.

Common upon *Pinus* sp. on the campus in Lawrence and vicinity. The infestation nowhere serious.

Pulvinaria innumerabilis Rathv. Plate XXI, figs. 1, 2.

On soft maple (*Acer* sp.), white elm (*Ulmus americana*), honey-locust (*Robinia* sp.), black walnut (*Juglans nigra*), in the vicinity of Lawrence, and on maple near Kansas City.

MEASUREMENTS IN MICROMILLIMETERS.

Host.	Antennal Segments.							
	1	2	3	4	5	6	7	8
Maple	45	48	63	51	36	27	24	45
Honey-locust	39	42	69	45	30	24	21	45
Walnut	45	48	63	51	36	27	24	45
"	45	51	66	60	36	24	24	42

Host.	Legs.					
	Coxa.	Troch.	Fem.	Tibia.	Tarsi.	Claws.
Maple	96	60	175	135	105	
Honey-locust	108	30	130	135	78	27
Walnut	90	60	147	129	66	24
"	108	30	180	150	84	25
White elm	....	63	174	159	90	21

Pulvinaria pruni, n. sp. Plate XXI, fig. 3; plate XXII; plate XXIII, figs. 1, 2.

Scale of female. Before the formation of the ovisac the scale is not unlike that of the fully mature *Lecanium hesperidum*, of delicate texture, plane surface, oval, 1–1.7 mm. in width, 1.5–2.9 mm. long. After oviposition the scale becomes more dense, recurved, plicate, when boiled in KOH and spread out under cover glass measures about 3 mm. in width and 4 mm. in length. Marginal spines simple. The base of ovisac ranges from 5 to 7 mm. in length and from 3 to 5 mm. in width.

The larvæ settle on the twigs and both sides of the leaves, preferably the under side, in either case choosing positions alongside the

veins. Longitudinal median carina prominent, undisturbed by shriveling of the body in the dried specimens.

The following measurements will show the characteristic structure of legs and antennæ of the adult female:

	Antennal Segments.							
	1	2	3	4	5	6	7	8
Scale on leaves	57	75	84	63	39	30	36	51
Scale on twigs	54	66	84	48	36	27	27	45

	Segments of Leg.						
	Coxa.	Tro.	Femur.	Tibia.	Tarsus.	Claw.	Breadth of femur.
Scale on leaves:							
Cephalic leg	120	135	240	255	108	30	111
Median leg	165	180	300	285	114	45	111
Posterior leg	180	180	300	255	115	45	105
Scale on twig:							
Cephalic leg	135	150	249	270	96	24	96
Median leg	159	174	285	240	105	36	108
Posterior leg	150	150	276	246	108	30	93

The above measurements were so characteristic, differing essentially (being in most cases uniformly larger) from either material or description before me, that I sent mounts, specimens *in situ* and notes to Dr. Howard, for comparison with departmental collections. In a letter he says: "I have asked Mr. Pergande to give it a careful examination, and he reports that it is apparently an undescribed species. We have received it before, and it bears the biologic number in our collection '6222.' We have received it from Charleston and Florence, S. C., both in 1894."

In our own collections it bears the lot number 399, which refers to like number in accession book. It is here recorded as being received from Wichita, Kan., July 23, 1895. The accompanying letter stated that these insects have been infesting the trees for three or four years.

On the twigs of this same plum tree *Aspidiotus ancylus* and *Aspidiotus forbesi* were present. This is the second instance of the association in goodly numbers of these two species, the first being lot D, on crab-apple.[4]

A number of the scales of *P. pruni* showed the effects of parasites. A specimen was sent to Doctor Howard, who finds it to be *Coccophagus lecanii* Fitch.

Parlatoria pergandei Comstock. Plate XXIV, figs. 1, 2.

This species is differentiated by Comstock from its nearest ally, *Parlatoria proteus* Curt., principally by the shape of scale of female:

4. This lot was discussed in this journal, vol. VIII, No. 1, p. 3. Mention is there made of the presence of another species besides *A. forbesi* upon the crab tree, but the determination of the second species as *A. ancylus* was not given at that time.

circular in *pergandei*, oblong in *proteus;* by the fourth lobe: present in *pergandei*, absent in *proteus*.

It is upon these characters that specimens in hand are determined as *pergandei*. Comstock's comparisons were probably made without specimens of *proteus* at hand, since he mentions in a foot-note Signoret's figures and description.[5] Later, however, Comstock speaks of receiving specimens of *proteus* from Signoret,[6] confirming his conception of this species.

The exact status of *pergandei*, however, does not seem to be fully settled. Professor Cockerell in his first check-list cites *pergandei* as a distinct species,[7] and in his first supplement it is located as a variety of *proteus*.[8] I have received it from Mr. Craw on orange from the type locality, Florida, labeled in agreement with Cockerell's supplement. Mr. C. L. Marlatt, who is now studying the genus, says "*pergandei* Comst. (merges into *proteus* Curt.)"[9] Doctors Berlese and Leonardi place Comstock's variety of *pergandei*, *cameliæ*, as *proteus*, var. *cameliæ*,[10] and other instances likewise might be cited.

With *pergandei* on orange branches from Florida (Craw), the *pergandei* under consideration on orange leaves and branches from a Lawrence greenhouse, *proteus* on *Pinus insignis* from Perth, Australia (Ckll.), and *proteus* on leaf of an orchid, Watagode, Ceylon (Green), before me, the following notes are made: Regarding the form of scale of female, I find "circular" scales among *proteus* and "elongate" scales among *pergandei*. No steadfast distinction either in shape or color of the female scale can therefore be noticed. Concerning the pygidium, the *proteus* on *Pinus* and the orchid show, in accordance with Comstock, the presence of plates in the location where the pointed fourth lobe is found in *pergandei*. *Proteus* further shows marginal undulations apparently independent of the lobes, the crests situated beneath (ventral aspect) the lobes and extending out about one-third the length of the lobes. These undulations are shown in the figure and are characteristic of the *proteus* on *Pinus*. They are not noticeable on the orchid insects.

Proteus, further, is not recorded, as far as I can ascertain, existing upon orange. I have received specimens in exchange on orange labeled *proteus*, but discriminations made upon the above basis showed the insects to be undoubtedly *pergandei*. The undulations along the posterior margin of *proteus* may be fairly constant; their presence in this one lot on *Pinus* does not warrant a statement of their perma-

5. Rep. Comm'r Agr. 1880, p. 327.
6. 2d Rep. Dept. Ent. Cornell Univ. 1883, p. 114.
7. Bull. Ill. St. Lab., vol. IV, p. 335, 1896.
8. Bull. Ill. St. Lab., vol. V, p. 397, 1899.
9. Marlatt, MSS.
10. Chermotheca Italia, Fascicola I, No. 2.

nence. The question then arises, Are the distinctions surrounding the fourth-lobe position of specific moment? In some genera they would not be. In *Parlatoria* all species are closely related, and hence distinctive structural characteristics, though slight, are of greater weight than in genera where distinctions are more marked. The presence of the fourth lobe, rudimentary, with papillar termination, then, should differentiate the species *P. pergandei* from the species *P. proteus* with its fourth rudimentary lobe showing plates extending beyond its caudal margin.

NOTES AND CORRIGIENDA.

Part I.

Aspidiotus obscurus Comstock as recorded was represented by only a few individuals upon one tree. I have since (October, 1899) found two black oak trees quite generally infested on both trunk and limbs. These trees are in a forest near Holton, Jackson county, Kansas.

On page 4, and wherever it occurs thereafter, the specific term *ancyclus* should be *ancylus*.

Part II.

Lecanium canadense Ckll. Occurred sparsely when found at time of collection, April, 1898. Last year the same conditions existed. This season it appears to be abundant upon elms in Lawrence and vicinity; in some cases assembled in clusters. I have found a species, alike in form, size, and color upon hickory, a suggestion for further observations upon the status of *caryæ* and *canadense*.

Lecanium cockerelli Hunter. This species has been found on plum in Nebraska (Bruner MSS.) I have found it on hickory this season (May) near Lawrence. The scale on hickory was well covered with a pruinose coating.

Lecanium macluræ being preoccupied, the term *Lecanium aurantiacum* is now offered in substitution.

Measurements of length and breadth of bodies of scales contain thereafter the abbreviation μ (Greek *mu*), which should be mm.



THE STRATIGRAPHY AND INVERTEBRATE FAUNAS OF THE JURASSIC FORMATION IN THE FREEZE-OUT HILLS OF WYOMING.

BY W. N. LOGAN.

With Plates XXV to XXXI, inclusive.

INTRODUCTION.

THE present article is based on the study of an assemblage of fossils collected by members of the Kansas University paleontologic party from the Freeze-out Hills of Wyoming during the summer of 1899. The expedition was under the direction of Dr. S. W. Williston, to whom the writer is indebted for assistance in securing these data.

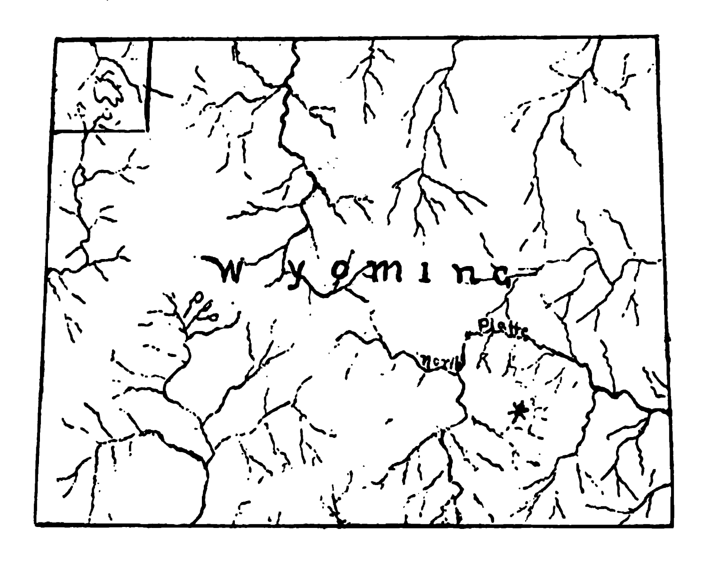
The specimens described in this article will be placed in the Kansas University Museum. The collections contain a majority of the species which have been described from the interior Jurassic province. A few of the species were collected by the writer from Como Bluffs, and many of the species described from the Freeze-out Hills were recognized there.

Geographic Position. The Freeze-out Hills of Wyoming are situated in the region of the sixth standard parallel north, between latitude 42° and 42° 15′ north, and between longitude 106° and 106° 30′ west. Their most southern extension lies about fifteen miles northwest of Medicine Bow, a station in southern Wyoming on the Union Pacific railroad. Sixty or seventy miles east of them the lofty peaks of the Laramie mountains rise, while the Seminole mountains approach them from the west, and from them the Snowy range is plainly visible on the south. The extensive orogenic movements which produced these surrounding mountain ranges left on the enclosed interior a number of anticlinal folds, of which the Freeze-out is a type. The hills, which are carved out of this anticline, are in the form of a semicircle, with a northwestern and southeastern extension of about twenty-five miles. They are located about twenty miles north of the region described by King in the report of the geology of the fortieth parallel.

Drainage. The Freeze-out Hills are separated from the Laramie range by the basin carved out by the Little Medicine Bow river and

its tributaries. The Little Medicine has in this region two principal branches. Sheep creek, its eastern branch, rises among the foot-hills of the Laramiė mountains, flows in a general southwest direction, and joins the river at a point almost directly east of the southern border of the Freeze-out Hills. Muddy creek, the western tributary of the Bow, has its origin north and west of the hills, flows for some distance nearly straight east, turns first southeast, then south, and enters the parent stream a few miles below the mouth of Sheep creek. Thus Muddy creek and its branches receive the northern and eastern drainage of the hills.

A few miles below the mouth of Muddy creek the Little Medicine Bow river, which, north of that point, flows for some distance almost directly south, turns sharply toward the west, and, flowing not far south of the hills, receives their southern drainage through its northern branches. On the west the drainage is effected through Troublesome creek, which is also a northern branch of the Bow.



Topography. The topographic features of the region are bold and rugged. The hills have been carved out of a great anticline by streams which in many instances flow almost parallel with the dip and across the strike of the strata. In general outline the group forms a great semicircle, with an abrupt central ascent and a gradually sloping circumferential descent. The maximum height of the hills is between 500 and 600 feet. The dip of the strata which compose them is about thirteen deg. although at first sight it appears much greater than that. The individual hills have an abrupt central or western approach and a far less precipitous outer approach. The occurrence of alternating

hard and soft layers has produced a number of terrace-like ledges which rise one above the other between the lowermost Red Beds and the Dakota at the summit.

In many places the topography approaches the Bad Lands type. The characteristic absence of vegetation of the Bad Lands is saved here to a limited extent by the presence, on the lower levels, of springs of water which irrigate the creek valleys. On the slopes, however, very little vegetation grows, but the dip of the strata combined with the thickness of the hard layers serves to produce the shelving rather than the sharp-crested form of topography which is so common in the Bad Lands.

Streams which have worked against the face of the monocline from the west have carved out broad, amphitheater-like basins. Those streams which flow toward the east have cut down through the hard strata of the Dakota and carved out similar basins in the softer strata of the underlying beds. The courses of these streams are marked through the Dakota by narrow, tortuous defiles or cañons.

The basal portion of the hills is formed by the Red Beds, while the main body of the hills is formed by the Jurassic and Atlantasaurus Beds. The hills are capped, usually, with a hard stratum of Dakota sandstone. This sandstone, broken into huge blocks by the sapping action of erosion, lies scattered upon the slopes. The soft clays underlying are first cut away by the action of the falling water, and the sandstones, being undermined, are broken off by their own weight and roll down the slopes of the hills. In some places the Jura is, by this means, concealed, although on the whole the exposures are very perfect.

STRATIGRAPHY.

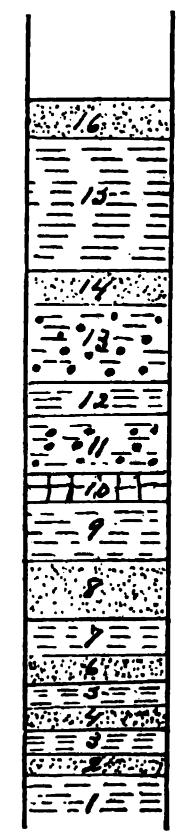
The Red Beds. The oldest rocks recognized in the Freeze-out Hills are the Carboniferous. They occupy the center of the anticline and are overlain by the Red Beds, which are composed of sandstones and reddish arenaceous clays, enclosing here and there lenticular masses of gypsum or gypsiferous clays. These beds are seemingly devoid of fossils, and are apparently conformable with the overlying Jurassic beds, of unquestionable marine deposition. The brilliant colors of the Red Beds, blended in places with the green of the vegetation and bluish clay of the Jura, produce in the hills a series of views remarkable alike for their beauty and brilliancy. At a point on the Dyer ranch the following stratigraphical conditions of the contact between the Red Beds and the Jura were noticed:

1.	Base, near top of Red Beds, reddish clay	2 ft.+
2.	White, indurated sandstone	4 in.
3.	Clay, light red	5 "
4.	White sandstone with reddish tinge	1 "

5.	Light red clay	2 in.
6.	White, slightly indurated sandstone	6 "
7.	Shale, reddish, changing to purple	4 ft.
8.	White, fissile sandstone	6 "
9.	Arenaceous clay of a dull red color	10 "
10.	White, laminated arenaceous limestone containing fossils	6 in.

This last stratum contains a characteristic Jurassic type, *Pseudomonotis curta* Hall. This is the first or lowest known fossil-bearing horizon of the Jura. Any division line placed between the Red Beds and the Jura lower than this fossiliferous statum would be an arbitrary one, as there appears to be no unconformity to mark their separation.

The term Jura-Trias, which has so long been applied to these beds, is no longer applicable, for the reason that the Jura is well differentiated by its faunas. This is true not alone of the Jura of this region, but it is also true of the formation everywhere in the West. The series of beds, however, which lie between the known Carboniferous and the Jura, and which constitute the Red Beds proper, might, in the absence of any means of differentiation, be called the Permo-Trias.



The Jura. Continuing the section already begun, we have, for number

11. Arenaceous clay of a somewhat shaly nature... 6 ft.

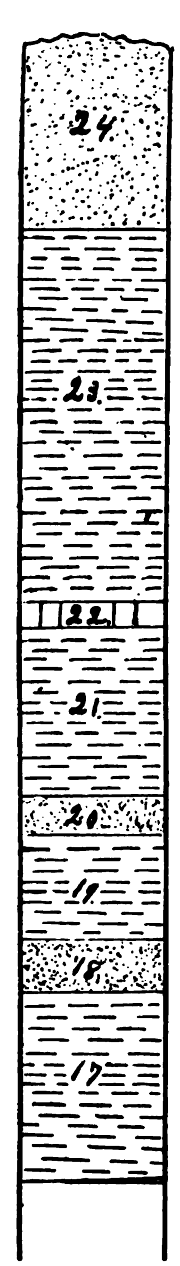
This layer contains, near the central portion, a more highly arenaceous stratum of a greenish color. It has scattered through it, also, at different levels, some rather large, brown, argillaceous concretions. The entire stratum seems to be unfossiliferous. But it may contain *Belemnites densus*, as it is often difficult to determine whether this fossil does or does not belong to the lower beds, since, on account of its abundance in some of the upper beds, it is scattered superficially throughout the full extent of the outcrop.

12. White, sandy clay .... 4 ft.

No invertebrate fossils were found in this stratum, but the remains of marine saurians belonging to the genera *Ichthyosaurus* and *Plesiosaurus* occur in considerable abundance.

13. Purplish fossiliferous clay containing calcareous nodules .... 20 ft.

The most abundant fossil in this stratum is *Belemnites densus*, which occurs distributed throughout the layer, while the other fossils are confined chiefly



to the calcareous concretions. From these concretions the following forms were obtained: *Pinna kingi*, *Pinna* sp., *Cardioceras cordiforme*, *Avicula beedei*, *Astarte packardi*, *Pentacrinus astericus*, *Tancredia bulbosa*, *Tancredia magna*, *Lima lata*, *Goniomya montanaensis*, *Avicula macronatus*, *Pleuromya subcompressa*, *Cardinia wyomingensis*, *Pseudomonotis curta*, *Belemnites densus*, and, in the clay, *Belemnites curtus*. This stratum contains also the remains of plesiosaurs and ichthyosaurs. It is the most abundantly fossiliferous of all the Jurassic strata. It is also one of the most persistent beds, and is everywhere characterized by the great abundance of belemnites.

14. Greenish-colored sandstone, separating into thin layers.................... 2 ft. to 5 ft.

This stratum contains considerable calcareous matter, is very persistent, and is easily recognized on account of its uniformly greenish color. The following fossils occur in it: *Camptonectes bellistriatus*, *Camptonectes extenuatus*, *Ostrea densa*, and *Ostrea strigilecula*.

15. Purplish clay containing considerable arenaceous inclusions.......................... 40 ft.

The clay contains, in the lower part, a thin stratum of sandy limestone in which the following fossils were found: *Pentacrinus astericus*, *Asterias dubium*, *Pseudomonotis curta*, *Avicula macronatus*, and *Ostrea strigilecula*.

The Atlantasaurus Beds. The last stratum is the last one containing marine fossils, and probably closes the Jura, but some of the non-fossiliferous beds lying above may belong to that formation. The succeeding stratum varies so much in thickness that it may represent the eroded surface of the Jura upon which the Atlantasaurus Beds were deposited.

16. Fine-grained, grayish-white sandstone.......................... 10 ft. to 125 ft.

The above stratum varies much in thickness within short distances. At one point on the Dyer ranch it has a thickness of only 10 ft., while a few miles southeast it reaches a thickness of 125 ft. The sandstone composing the layer is of nearly uniform color and texture. Its in-

duration is only moderate, and it weathers into many grotesque forms Cross-bedding is well exhibited by it in many localities.

17. Purple to greenish-colored clay.................................... 60 ft.

This is apparently an unfossiliferous layer, except in the uppermost horizon, where species of dinosaurs belonging to the genera *Brontosaurus* and *Morosaurus* occur.

18. Sandstone, grayish to light brown..................... ..... 10 ft. to 20 ft.

The above sandstone presents some very interesting stratigraphic phenomena. It has, at the base, a layer of conglomerate about 2½ ft. thick. The conglomerate is composed of small silicious and argillaceous pebbles, and is not very coherent. Something like two feet of sandstone rests upon the conglomerate; the bedding planes of the sandstone are oblique to the bedding planes of the beds above and below. Succeeding the sandstone above is 6 in. of sandstones in very thin layers, with lignitic seams along its horizontal but wavy bedding planes. The above is overlain by 4 in. of conglomerate, followed by 1 in. of sandstone with oblique bedding planes. Overlying this layer is a thin layer of sandstone in which the bedding planes are horizontal. The remainder of the stratum is made up of sandstone with the bedding planes as follows: 1 ft. oblique; then 3 in. horizontal; then 2 ft. oblique; and finally 3 in. horizontal. The stratum furnished in one place the trunk of a large fossil tree and a large number of fossil cycads. Fragments of fossil wood were found in a number of places, but cycads in only the one. Fragments of a hollow-boned dinosaur were found in one place in the horizon.

19. Drab-colored clay.................................... 30 ft. to 40 ft.

This stratum contains the bones of the large dinosaur, *Brontosaurus*. Otherwise it appears to be unfossiliferous.

20. Fissile, brownish sandstone............................. 4 ft. to 5 ft.

No fossils were found in this sandstone, and the most characteristic feature about it is its uniformly brown color. It seems to be moderately persistent, as its occurrence in many places in the hills was noticed.

21. Bluish-green clay containing very small concretions............. 30 ft.

In the bone quarries of this horizon, which furnished species of *Brontosaurus*, *Morosaurus*, and *Diplodocus*, were found specimens of (*Planorbis*) *veternus* and *Valvata leei*. This is the lowest horizon at which any of these non-marine invertebrates were noticed. It is probable that they will be found lower down, as the dinosaurs occur much lower.

22. Brown to bluish-gray arenaceous limestone.............. 8 in. to 1 ft.

This stratum contains the following non-marine invertebrate forms: *Unio knighti*, *U. willistoni*, *U. baileyi*, *Valvata leei*, and (*Planorbis*) *veternus*. Species from the same genera have been described by Meek from a similar stratum of limestone in the Black Hills. As these occupy much the same stratigraphical position they are probably the same age. The *Lioplacodes* seems to be identical with that described by Meek in the Geology of the Upper Missouri.

23. Drab-colored clay.. 70 ft.

Species of the genera *Brontosaurus*, *Diplodocus*, *Morosaurus*, *Stegasaurus* and *Allosaurus* occur in this horizon. Portions of species of all these genera were found in one quarry by the Kansas University collecting party. The clay is of that quality usually designated as "joint" clay. It contains in places iron and argillaceous concretions of small size. The iron, and sometimes the bones, are covered with selenite crystals.

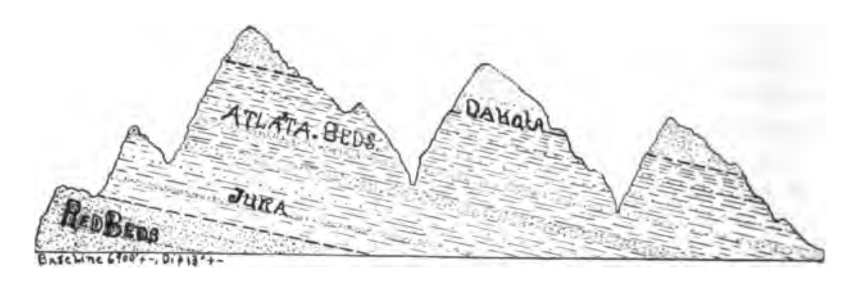
24. Grayish-white sandstone.. 50 ft.

This layer forms a conspicuous capping for the hills, and is the highest remnant of the anticline. It breaks up into large blocks, which lie scattered along the slopes of the underlying softer beds. Its erosion and disintegration is accomplished chiefly by sapping. No fossils were found in this stratum, and its true position is in doubt.

The Dakota. The Freeze-out Hills are capped with a heavy ledge of sandstone, which may represent the basal member of the Dakota, although its age is in doubt. So far no paleontologic evidence as to the age of these beds has been found. From their stratigraphical position, however, they have been placed in the Dakota.

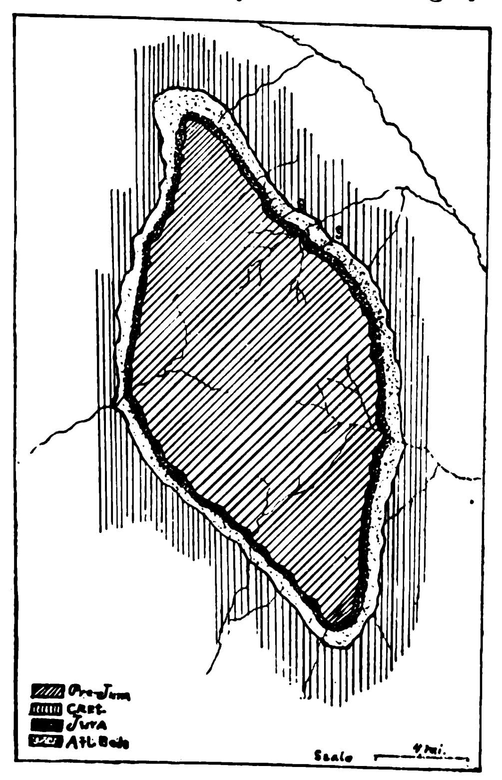
This grayish-white sandstone layer breaks up into immense blocks, which lie scattered in many places from summit to base of the hills. It weathers in some places to a rusty iron color, and in other places has the appearance of hematite. The base of the sandstone is apparently conformable with the underlying beds, although it is conglomeratic. The stratum forms the crests of the greater part of the hills and dips rapidly down toward the surrounding plain. Its detailed stratigraphy, taken from an outcrop about one mile northwest of the T. B. ranch, is as follows:

1. At the base, resting on the clay of the Atlantasaurus beds, a layer of fine-grained sandstone.............................. 6 ft.
2. A layer of conglomerate, composed of small pebbles............ 10 "
3. A layer of coarse-grained sandstone........................... 10 "
4. At the summit, fine-grained sandstone.......................... 25 " +



All of these layers exhibit the phenomena characteristic of shallow-water deposits. The conglomerate is composed of small pebbles, the largest noticed not exceeding an inch in diameter, and the average being only about one-third that size. The pebbles are, for the most part, argillaceous and silicious. Induration is more pronounced in the case of the fine-grained sandstone, in which the cementing material is almost wholly siliceous.

There occur occasionally throughout the region large lenticular masses of sandstone, in which the cementing material is iron oxide. These masses are by far the most highly indurated of the group. The iron was probably deposited under the same conditions which prevail in certain regions to-day. At the present day, iron, in the form of a soluble carbonate, is being brought into marshes and bogs, and deposited in the form of an oxide or a carbonate. To assume that the iron of the Dakota formation was deposited under similar conditions seems to be in accord with a logical interpretation of the facts.



The quartz grains of the Dakota sandstone are held together by at least three kinds of cementing material, namely, iron oxide, calcium carbonate, and silica. The degree of hardness of the stone depends upon

the amount of the last-named substance. The degree as well as the uniformity of the induration depend upon the conditions of sedimentation and subsequent stratigraphical relations. A homogenous stratum of sand in the belt of induration is more favorable to the agents of cementation than a heterogeneous stratum composed of sand and clay, for the reason that the former permits the freer circulation of solutions. Again, if the mineral in solution be silica, the presence in the rock of large quantities of quartz will favor deposition of the silica, because of the affinity which causes one mineral to select its kind in deposition or recrystallization—a principle which is well illustrated in the process of enlargement of crystals by metasomatism.

The character of the cementing substance depends upon the character and solubility of the rocks through which the percolating waters pass before reaching the zone of induration. If the surface rocks and the superincumbent rocks be limestones or calcareous shales, the cement will be, for the most part, calcite. If the source of the descending waters be marshes into which the surface-waters are bringing soluable iron compounds, the cementing agent is very likely to be some form of iron. If, on the other hand, the surface-waters and the percolating waters find their courses in sandstone, quartzite, or other quartz-bearing rocks, the sandstone will be cemented by silica.

The induration of these sandstones is a continuous process which began with the deposition of the beds, and is still taking place. It is taking place not alone in the deep-seated zone, but also in the peripheral zone of weathering. Depth of burial had its influence by bringing the quartz grains closer together, and thus leaving smaller spaces to be filled by the cementing substance. The stratum of sandstone which becomes indurated while deeply buried is not constantly in a zone of underground waters, but is alternately in a zone of saturation and in a zone of imbibition. While in the zone of saturation, the rock spaces are filled with water containing the cement in solution. When, however, by a diminution in the supply of water, the stratum is brought above the zone of saturation into that of imbibition, evaporation takes place, and the minerals held in solution are deposited.

Induration continues, however, even after the rocks have been upturned by orogenic movement and the overlying rocks removed by erosion. In the zone of weathering, the ascending waters are bringing up minerals in solution to be deposited as the water is evaporated. This form of deposition is very common in arid or semi-arid regions. In western Kansas, ascending waters passing through a bed of calcareous shales have, in one instance, built up a cone twenty feet high. Where the underground waters come to the surface in some of the

Tertiary rocks of the arid plains, these rocks have reached a high degree of induration produced by this mode of deposition.

PALEONTOLOGY.

Jurassic. The Jurassic period was a period of expansion for marine life. It was a period when, by the encroachment of the oceanic waters, great epicontinental seas and bays were formed. At least three of these bodies of water existed on the continent of Eurasia and one upon the American continent, while there were less extensive encroachments on all the large land masses. These epicontinental seas, by furnishing additional feeding grounds, increased to a marked degree the number of marine organisms. And in so far as these seas restricted the land area they restricted also the development of terrestrial life.*

During Upper Jurassic time three faunal stages marked the growth of marine transgression upon the borders of the continents. These stages are known in England as the Lower Oolyte, the Middle Oolyte, and the Upper Oolyte. Only one of these three stages, the Upper Oolyte, is represented in the Jura of the American interior province, and probably only the middle part of that. In other words, of the three Upper Jurassic faunas recognized in the Pacific coast deposits of California and in northern Eurasia, only one is recognized in the Wyoming Jura.

The discovery of beds of Jurassic age in the interior was first announced by Meek in 1858.† In correlating these beds with the Jura of the old world, the writer says: "The organic remains found in these series present, both individually and as a group, very close affinities to those in the Jurassic epoch in the old world; so close, indeed, that in some instances, after the most careful comparisons with figures and descriptions, we are left in doubt whether they should be regarded as distinct species or as varieties of well-known European Jurassic forms. Among those so very closely allied to foreign Jurassic species may be mentioned an ammonite we have described under the name of *A. cordiformis*, which we now regard as probably identical with *A. cordatus* of Sowerby; a gryphæa we have been only able to distinguish as a variety from *G. calceola* Quenstedt; a pecten scarcely distinguishable from *P. lens* Sowerby; a modiola very closely allied to *M. cancellata* of Goldfuss; a belemnite agreeing very well with *B. excentricus*."

Since the publication of the above statements by Meek the paleontology of the European Jura has been more completely worked out, and some of the faunas, particularly that of northern Russia, are

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*For the principles involved in these statements see "A Systematic Source of Evolution of Provincial Faunas," by T. C. Chamberlin. (Jour. Geol., vol. VII, p. 597.)

†Geological Report of the Exploration of the Yellowstone and Missouri Rivers.

found to have still closer affinities to the American interior fauna. The Jurassic faunas of America have also received many additions at the hands of the American paleontologists Gabb, Hyatt, White, Meek, Whitfield, Whiteaves, Smith, and Stanton. From a study of the evolution and distribution of Jurassic faunas, it has developed that the American interior fauna is largely a heterochthonous fauna which has migrated from northern Eurasia. As a whole it is radically different from its equivalent in time as it is represented in the Pacific deposits of California.

The following comparison of forms which seem so closely allied as to deserve to be called varieties of the same species will serve to show the close affinity of the fauna of the interior to the fauna of Eurasia:

Belemnites panderanus d'Orb....... = *Belemnites densus* Mk.
Astarte duboisianus d'Orb .... = *Astarte packardi* White.
Pentacrinus pentagonites Golldf.... = *Pentacrinus astericus* Mk.
Avicula tenuicostata Roem.......... = *Avicula mucronata* Mk.
Goniomya dubois d'Orb............. = *Goniomya montanaensis* Mk.
Cardioceras cordatus Sowerby...... = *Cardioceras cordiforme* Mk.
Ostrea duriscula d'Orb.............. = *Ostrea densa*, n. sp.
Gryphea calceola Quen............. = *Gryphæa nebrascensis* Mk.

The fauna taken as a whole exhibits the close relationship in a much more forcible manner than the comparison of a few species can show.

The Jurassic fauna of the whole interior is essentially the same as the fauna of the Black Hills, which Neumayr, in his Geographische Verbreitung Juraformation, shows to be a northern fauna closely related to that of northern Eurasia. To explain the presence of this northern fauna in the interior and its dissimilarity to the Pacific fauna of California, he postulates the southern extension of an arm of the Arctic ocean at a point east of the Rocky mountains and the existence of a land barrier between the two provinces.

DESCRIPTION OF SPECIES.

In order to give a comprehensive idea of Jurassic fauna of the Freeze-out Hills, I have brought together and described all of the species found there, although a large part of them are already known from other localities. Many of the specimens described here have been recognized in the Black Hills, in the Yellowstone national park, on Wind river, and on Queen Charlotte islands.

Pentacrinus astericus Meek and Hayden. Plate XXV, figs. 4, 5, 6, 7.

Many fragments of crinoid stems were collected from a thin stratum of arenaceous limestone occurring in the clay of No. 15. Fragments were also found in the nodules of No. 13. These forms are all referred to the species *Pentacrinus astericus*.

The stems are composed of small pentagonal joints. The margins

of the joints are crenulate and the articulating surfaces are ornamented by five petalloidal areas radiating from a central canal. The nodal joints are ornamented with rounded, tapering cirri, which are composed of small, disk-like joints. No complete specimens of the calyx were obtained, but from one or two incomplete ones I judge the size is small. The free arms are several inches in length.

Dimensions of joints: Length, 1 mm.; diameter, 2 to 3 mm.

Geological horizon: Fragments occur somewhat abundantly in No. 13, but more abundantly in No. 15.

Locality: Freeze-out Hills, Wyoming; also Black Hills, South Dakota.

Remarks: This species seems closely allied to *Pentacrinus subangularis* Mill., from the Upper Lias of northern Eurasia. When the calices are compared, greater differences may be noted than are revealed by the stems.

Pleuromya subcompressa Meek. Plate XXVI, figs. 4, 7, 8.

Shell medium size, convex, greatest convexity in the anterior region, form triangularly wedge-shaped. The beaks are prominent, extending above the hinge line and slightly recurved. They are somewhat flattened anteriorly. The hinge is short and straight. The posterior border is nearly straight; straight in some specimens, and slightly curved in others, in which case the convexity of the border is greatest near the median line. The basal margin has a curved outline, the anterior basal portion of which is truncated.

The dorsal margin is short and rounds off gradually into the two adjacent margins. The surface of the shell is ornamented with concentric ridges, which are somewhat irregular in degree of prominence and form nearly parallel lines on the posterior portion of the shell. In the majority of specimens the ridges are more prominent on the posterior and ventral portions of the shell.

Dimensions: Length, 40 mm.; width, 25 mm.; height, 8 mm.

Geological horizon: This species occurs in the arenaceous nodules of No. 13 of the section. The same stratum also furnishes *Astarte packardi*, *Pinna kingi*, *Goniomya montanaensis*, *Belemnites densus*, etc.

Locality: Freeze-out Hills, Wyoming; also reported from Utah, Montana, Idaho, Colorado, and Dakota.

Pleuromya subcompressa is found also in the Queen Charlotte fauna of the Pacific, and assists in its correlation with the fauna of interior.

Ostrea strigilecula White.

This species is so variable in form that a number of forms have been drawn and described by the author in order to bring out these differences.

Variety I, plate XXVIII, figs. 1, 2, 5.

Shell small, irregular in form, sometimes almost cup shaped. Lower valve deep and attached by its entire surface, which is often nearly circular in shape; muscular impression large, as is also the ligmental area. Surface of the valve lamellose or strongly wrinkled.

Variety II, plate XXVIII, figs. 3, 4.

Shell small, varying in general shape from oblong to ovate, nearly flat, most capacious near the beak; interior of shell smooth, presenting a glazed appearance; ligmental area quadrangular and depressed centrally.

Variety III, plate XXVIII, fig. 6.

Shell larger than the second variety, ovate in general outline, beak acute, with centrally depressed triangular ligmental area; muscular impression faint, while in the other varieties it is well marked.

Dimensions: Length, 30 mm.; width, 20 mm.; height, 5 mm.

Geological horizon: These forms occur in the lower part of stratum No. 14, and also in a thin stratum of No. 15.

Locality: The Freeze-out Hills, Wyoming.

Remarks: *Ostrea strigilecula* has a wide distribution in Jurassic deposits of the interior province. It has been recognized wherever this formation has been recognized.

Lima lata ?, n. sp. Plate XXX, figs. 2, 3.

Shell subtriangular, not large for the genus, capacious, umbonal region gibbous, dorsal portion slightly convex. The beak of the shell is moderately acute, and is turned so as to point in the direction of the anterior border. The hinge line is long, the greater part of its extension being between the beak and the anterior border. The anterior border, as well as the dorsal, is broadly rounded. The posterior border is nearly straight, passing into the adjacent borders by rather abrupt curves. The test of the shell is thick. The surface is ornamented with fine radiating striæ and concentric lines of growth.

Dimensions: The full length of the shell is unknown, but is probably about 55 mm; width, 40 mm; height, 10 mm.

Geological horizon: This species occurs in the nodules of stratum No. 13. It is not of frequent occurrence, as only a few specimens were obtained. It is associated with *Pinna kingi*, *Pleuromya subcompressa*, *Belemnites densus*, *Pseudomonotis curta*, *Astarte packardi*, *Goniomya montanaensis*, etc.

Locality: The Freeze-out Hills, Wyoming.

Remarks: As no complete specimens of this form were found, its determination is somewhat doubtful. The characters of the beak are somewhat uncertain in the specimen figured.

Tancredia bulbosa Whitf. Plate XXVIII, figs. 11, 12.

Shell small, triangular in general outline. The beaks are prominent, slightly incurved, subcentral, and project slightly beyond the cardinal line. The anterior portion of the shell is marked by a broad, shallow depression, which passes transversely across that portion of the shell, expanding gradually as it approaches the dorsal margin. The dorsal border is almost straight, but is rounded at the extremities. The posterior and the anterior borders are both somewhat sharply rounded. The surface of the cast is smooth, but exhibits fine concentric markings.

Dimensions: Length, 20 mm.; width, 17 mm.; height, 4 mm.

Geological horizon: The arenaceous nodules of stratum No. 13 contain numerous representatives of this species. Its associates are the fossils already mentioned for that stratum.

Locality: The Freeze-out Hills, Wyoming.

Remarks: This species is somewhat abundant. The test is rarely found, but the casts are numerous.

Pinna kingi Meek. Plate XXIX, figs. 3, 6.

Shell moderately large, expanding rapidly toward the posterior margin. The test is of medium thickness, with a prismatic structure, dark colored; the pearly layer absent in the specimen. The dorsal border is slightly concave in the central region, but convex in the posterior region, in which region the ventral border is slightly concave. The posterior margin of the shell is rounded and that portion of the shell body is reflex. The surface has a prominent carina extending from the beak to the posterior margin, forming an angle, which is slightly nearer the ventral than the dorsal border. The dorsal side of the angle is concave, while the ventral is convex. The surface of the shell is ornamented by longitudinally radiating striæ extending in lines parallel with the borders, also by curved lines of growth, which arise from the dorsal border.

Dimensions: Length, 13 cm.; width, 6 cm.; height, 1 cm.

Geological horizon: *Pinna kingi* occurs somewhat abundantly in No. 13 of the section. It is found with *Astarte packardi*, *Belemnites densus*, *Pleuromya compressa*, *Goniomya montanaensis*, etc.

Remarks: The above may be the same species as *Pinna breweri* Gabb, described from the Chico of California. This seems to be its nearest connection, and a comparison of the forms will be necessary to the positive identification of their relationships.

Pinna sp. Plate XXIX, figs. 1, 2.

The casts of several smaller, more convex individuals were discovered associated with *Pinna kingi*. The surface ornamentation of the

forms seems to consist wholly of a subcentral carina and almost parallel, slightly radiating lines of growth. This may be an apparent variation in the young of the above-described species which does not find expression in the adult forms.

Tancredia magna, n. sp. Plate XXX, fig. 1.

Shell large, subovate in general outline. The beaks are prominent, inflated, incurved, and project a short distance beyond the cardinal line. They are placed posteriorly with regard to the cardinal margin. The hinge line is straight and has a long extension anterior to the beaks. The dorsal border is slightly convex and rounds into the adjacent borders. The posterior border is more broadly curved than the anterior. The anterior portion of the shell is crossed by a transverse depression, which originates near the beak and gradually expands toward the basal border. The dorsal border of this depression forms a rather sharp ridge, which is more pronounced near the beak. The surface of the cast is marked by broad bands and fine concentric lines of growth.

Dimensions: Length, 45 mm.; width, 38 mm.; height, 10 mm.

Geological horizon: This species is found in stratum No. 13 of the section, where it is associated with the fossils already mentioned as characterizing that horizon.

Locality: The Freeze-out Hills, Wyoming.

Remarks: This shell is so much larger than *T. bulbosa* Whitf., and, as there appear to be no intermediate forms, I think it must constitute a new species. It is not so abundant as the latter.

Camptonectes bellistriatus Meek. Plate XXX, figs. 7, 8.

Shell large, circular or orbicular in outline. moderately convex. The hinge line is short and straight. The posterior ear is about one-half the size of the anterior ear. The beak is obtusely angular. The surface of the shell slopes gradually back from the beak and attains its maximum convexity at about one-third the distance from the beak to the posterior margin. The surface of the shell is almost smooth, but possessing scarcely discernible radiating striæ, which are crossed by several moderately strong concentric lines of growth and finer striæ. The left valve is rather more convex than the right. The anterior ear of the right valve bears a deep notch, which separates it from the body of the shell.

Dimensions: Lenth, 50 mm.; width, 40 mm.; height, 8 mm.

Geological horizon: The greenish-colored sandstone of No. 14 of the section bears numerous representatives of this form. It is associated with *Camptonectes extenuatus*.

Remarks: The fauna of the hills has numerous representatives of this species. It is also well represented in many other localities in the interior.

Cardioceras cordiforme **Meek. Plate XXVII, figs. 1-12.**

Shell from medium to large size; cross-section of outer volution near the aperture nearly triangular; the dorsal side of the outer volution sloping gradually to a rather prominent keel in the shell, but to a rounded margin in the cast. The ventral side of the volution passes almost vertically to the inner volution, and in old individuals forms a reentrant angle with the inner volution. The outer volution of the shell expands rapidly toward the aperture, at which point it equals about one-third the full diameter of the shell. The umbilicies equal in diameter nearly one-third of the outer volution. The surface of the shell is marked by transverse, flexuous costæ, which are somewhat variable in prominence and are frequently bifurcated at one-fourth the distance from the dorsal to the umbilical border. The bifurcated costæ are separated by a simple costa, which fades out before reaching the umbilical border. The costæ form a sigmoidal curve in passing from the dorsal to the umbilical border.

The septa are marked on but few of the sandstone casts; they are somewhat crowded. The dorsal lobe is higher than wide, and has two terminal lobes, each ornamented with numerous smaller digitations. It also possesses two lateral lobes similarly ornamented and followed below by two minor lobes. The dorsal saddle is somewhat narrower than the dorsal lobe, and is pierced at the terminus by a small lobe, and laterly by the lateral branches of the adjacent lobes, which form for it one terminal and five lateral branches. The first lateral lobe nearly equals in length the dorsal lobe; it is ornamented by three terminal and two lateral branches, each having minor digitations. The first lateral saddle is much narrower than the first lateral lobe, and is ornamented with two small terminal branches and several lateral ones, all of which are unequally digitate. The second lateral lobe is a little more than half the size of the first, and has two terminal digitate branches and two smaller lateral ones. The remainder of the septum is not present in a determinable condition in any of the specimens collected.

Dimensions: Diameter of a medium specimen, 80 mm; diameter of an outer volution, 35 mm.

Geological horizon: Species occurs in moderate abundance in the clay and arenaceous nodules of No. 13 of the section. It is associated with *Astarte packardi*, *Belemnites densus*, *Pinna kingi*, etc.

Locality: Freeze-out Hills, Wyoming, and Black Hills, Dakota.

Remarks: This species seems to be closely related to the northern European species *Cardioceras* (*Quenstedioceras*) *lamberti*, which is described from Russia.

Camptonectes extenuatus Meek and Hayden.

Shell medium size, ovate or suboval in outline. The hinge line is straight, equaling in extent nearly one-half the length of the shell. The ears are large and triangular; the margins of the posterior one slopes abruptly backward to the body of the shell. The beaks are small, not projecting above the hinge line, and somewhat sharply rounded. The surface of the shell is marked by fine radiating striæ, which diverge from the median line and converge toward the lateral border; also by concentric striæ, which cross the former at right angles.

Dimensions: Length, 30 mm.; width, 22 mm.; height, 8 mm.

Geological horizon: These fossils occur in the greenish-colored sandstone of No. 14 of the section.

Locality: The Freeze-out Hills, Wyoming; also reported from Dakota.

Remarks: *C. curvatus*, described by Whiteaves from the Jurassic fauna of the Queen Charlotte islands, is probably a synonym of *C. extenuatus*. The following forms are recognized in both faunas: *Belemnites densus*, *B. curtus*, *Astarte packardi*, *Pleuromya subcompressa*, *Avicula* (*Oxytoma*) *mucronata*, *Gryphæa nebrascaensis*, and *Camptonectes extenuatus*.

Cardinia wyomingensis, n. sp. Plate XXV, fig. 8.

Shell large, convex, subquadangular, length more than twice the width. The hinge line is long and straight. The posterior border forms an acute angle with the ventral border, which is long and straight. The anterior border is rounded. The contour of the shell forms a rounded escarpment, which extends from the umbonal region to the posterio-ventral border angle. The test of the shell is thick. The surface is ornamented with prominent concentric lines of growth·

Dimensions: Length, 90 mm.; width, 35 mm.; height, 8 mm.

Geological horizon: A few representatives of this form were found in stratum No. 13, in which they were not abundant. They occur with the fossils already mentioned as belonging to that horizon.

Locality: The Freeze-out Hills, Wyoming.

Remarks: This is a rare form in the Jurassic fauna, as very few specimens were collected. The genus seems well represented in the European fauna of the Jura.

Pseudomonotis curta Hall. Plate XXX, fig. 5.

Shell (left valve) of medium size, obliquely suborbicular, unequivalve, convex. The beaks are obtusely pointed and prominent, extending above the cardinal line, and having the apex slightly incurved. The hinge line scarcely equals half the length of the shell. The an-

terior wing is small, and rounded toward the beak. The surface is bent toward the opposite valve so as to leave a small opening between the valves near the anterior margin. The posterior wing is larger, and the surface is flat near the anterior margin. The surface of the shell is ornamented with fine radiating plications, which are crossed by concentric striæ, producing small nodes at the points of intersection. These nodes are prominent near the basal margin in most specimens, but rarely occur in the region of greatest convexity, which is nearly always smooth. The surface markings are not so conspicuous on the right valve. The anterior wing of this valve is separated from the body of the shell by a very narrow slit or groove.

Geological horizon: This species occurs in the sandstone of No. 10, and also in the nodules of No. 13. In the first stratum it has no associates. In the latter, it has associated with it the fossils already enumerated from that horizon.

Locality: The Freeze-out Hills, and Como Bluffs, Wyoming; also occurs in Black Hills.

Remarks: This fossil marks the lowest limit of the fossiliferous belt of the Jura-Trias rocks of this region. It occurs in a thin stratum of limestone intercalated between beds of shale. Below the limestone stratum appear the characteristic Red Beds of the Permo-Trias. Above are the fossiliferous beds of the Jura.

Pholadomya robusta, n. sp. Plate XXVI, figs. 5, 6.

Shell convex, elongate-oblong in general outline. The posterior umbonal region is the area of greatest convexity. The cardinal line is long and moderately straight. The beaks project a little beyond the cardinal line and are slightly incurved. The dorsal border is broadly convex. The posterior and the anterior margins are more abruptly rounded.

The surface of the shell is ornamented by several costæ, radiating from the beaks and curving posteriorly as they pass to the dorsal border. The costæ are crossed by prominent concentric undulations.

Dimensions: Length, 26 mm.; width, 20 mm.; height, 8 mm.

Geological horizon: The species occurs in the abundantly fossiliferous stratum, No. 13 of the section. It is associated with *Pinna kingi*, *Belemnites densus*, *Tancredia magna*, *Astarte packardi*, *Pleuromya compressa*, etc.

Locality: The Freeze-out Hills, Wyoming.

Remarks: The above-described species differs from *Pholodomya kingi*, described by White, in the matter of size and surface ornamentation. It does not appear to have any very close European affiliations.

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Avicula beedei, n. sp. Plate XXVIII, fig. 10.

Shell convex, medium in size, arcuate-oblong in general outline, greatest convexity in the anterior region. The hinge line is short and straight. The beaks are small, somewhat pointed and turned toward the dorsal border, so that the line of greatest arch of the shell is a sigmodial curve. The anterio-dorsal border of the shell is extended into a moderately large wing, which has its margin rounded and curves slightly toward the beak anteriorly; the posterior border a somewhat abrupt curve. The ventral and dorsal borders are convex, the ventral border having the greatest convexity. The surface of the shell is ornamented by obscure radiating lines and more pronounced concentric lines of growth.

Dimensions: Length, 30 mm.; width, 12 mm.; height, 6 mm.

Geological horizon: No. 13 of the section furnished a few specimens of this form. The species occurs with *Belemnites densus*, *Pinna kingi*, *Pleuromya subcompressa*, *Tancredia magna*, etc.

Locality: The Freeze-out Hills, Wyoming.

Remarks: This specimen, the type, was collected by Dr. J. W. Beede, in whose honor it has been named. It is not a common form in the Jurassic fauna of this locality.

Astarte packardi White. Plate XXVII, figs. 13, 14.

Shell medium in size, convex, subcircular in general outline. The beaks are small, subcentrally placed, and prominent. The anterior margin is short and slightly convex. The posterior margin forms a broad subelliptical curve. The hinge line is short and ornamented with two transverse cardinal teeth, the anterior of which is the larger. The lateral teeth are not present. The surface of the shell is marked by numerous regular concentric undulations, the intermediate spaces being occupied by minute concentric striæ. The casts of the shell exhibit at the margin a row of depressions which correspond to minute projections on the shell border. Test of the shell moderately thick.

Dimensions: Length, 20 mm.; width, 17 mm.; height, 8 mm.

Geological horizon: This species is very abundant in the arenaceous nodules of No. 13 of the section, where it is associated with *Pinna kingi*, *Pleuromya compressa*, *Goniomya montanaensis*, *Belemnites densus*, etc.

Locality: Freeze-out Hills, Wyoming; also from Lake Como, Wyoming, from which place it was first described by White.

Remarks: Next to *Belemnites densus* this species is the most abundant species in stratum No. 13. The shells are in a good state of preservation, as they have been crystallized for the most part into

calcite during the process of fossilization. The species seems very closely allied to the northern European form, ***Astarte duboisiana*** d'Orb.

Goniomya montanaensis Meek. Plate XXVI, fig. 1.

Shell oblong-arcuate in general outline, convexity regular; hinge line long, nearly straight, extending from the beak posteriorly by nearly its full length. The beaks are prominent and raised above the cardinal line. The dorsal border is broadly rounded. The posterior margin forms an obtuse angle, with its apex near the median line of the border; the anterior margin is rounded. The umbonal region of the shell is but slightly convex, nearly flat. The surface of the shell extending from the beak to the middle of the posterior margin forms a rather prominently curved arch. The surface ornamentation consists of prominent, rounded ridges, which in passing back from the beak form in the umbonal region quadrangular figures; then for about one-third the distance down the dorsal slopes the quadrangular figures are succeeded by triangular ones which have an acute angle on the dorsal slope. These in turn are replaced by figures with the dorsal angle growing more and more obtuse, until near the dorsal border the figures become almost elliptical in form. The surface is also marked by finer concentric lines of growth.

Dimensions: Length, 50 mm.; width, 23 mm.; height, 8 mm.

Geological horizon: The species occurs in the arenaceous nodules of No. 13 of the section, where it is associated with *Belemnites densus*, *Astarte paokardi*, *Pinna kingi*, *Pseudomonotis curta*, *Pleuromya subcompressa*, etc. It is also reported, as stated below, from the Yellowstone cañon, Montana.

Remarks: The typ› specimen of this species was described by Meek in the United States Geological Reports for 1872. Its determination was based upon an imperfect specimen, and from the figure and description it is difficult to say whether or not the Wyoming species is the same. It is placed here, however, provisionally.

The species is also very closely allied to the European species, *Goniomya ornati* Quenst., described from the Jurassic fauna of Russia and the Ural mountains. So close is its connection that it may be merely a variety of the European species.

Goniomya sp. Plate XXVI, fig. 2.

The cast of a shell which appears to belong to a different species was found associated with *Goniomya montanaensis*. It appears from the cast that it is a much narrower and proportionally longer shell than the latter. The surface markings and other characteristics present are analogous to those of the above-named species.

Ostrea densa, n. sp. Plate XXVIII, fig. 7.

Shell (left valve) very large, subquadrate, test very thick. The beak is truncated and possesses a large quadrangular area which is not depressed. The anterior margin is straight while the dorsal and the ventral borders are convex. The posterior margin is unknown. The valve is moderately capacious. The exterior surface is smooth and nearly flat. The ventral border has about one-half the thickness of the dorsal, which is very thick.

Dimensions: The full length of the shell is unknown. The width exhibited by the largest fragment is 65 mm.; the thickness of the test, 10 mm.

Geological horizon: This species is found in stratum No. 14, where it is associated with *Ostrea strigilecula* and *Pentacrinus astericus*.

Locality: The Freeze-out Hills, Wyoming.

Remarks: This species is not abundant and no complete specimens were found. Several fragments were observed, however.

Ostrea comoensis, n. sp. Plate XXVIII, fig. 9.

Shell (left valve) small, capacious for size of shell, convex; test thick; the anterior margin acute; the posterior margin somewhat wavy, irregular; ventral border concave; dorsal border convex, wavy. The interior of the shell is smooth. The muscular impression is large and projects above the surface of the shell. The ligmental area is quadrangular. The exterior of the shell is lamellose.

Dimensions: Length, 40 mm.; width, 21 mm.; height, 3 mm.

Geological horizon: This species also occurs in the lower part of stratum No. 14, where it is associated with the above-named species

Locality: The Freeze-out Hills, Wyoming.

Remarks: Associated with the above is the fragment shown in Plate IV, fig. 18. This fragment evidently belongs to a new species, but as the essential parts are wanting its form and description cannot be given.

Belemnites densus Meek. Plate XXVI, fig. 9.

Guard medium in size, conical in general outline, although the proximal end may be nearly straight. The distal portion tapers gradually to a point. In cross-section the guard is from oval to subcircular. The guard substance is thick and bears a distinct prismatic structure, which radiates in sharp but divergent rays from a line coincident with the center of the phragmacone and subcentrally placed. A cross-section of the guard shows fine concentric lines of growth. The phragmacone in varying length expands from below upward and is slightly curved. The shell substance becomes thinner toward the proximal end. The surface of the guard is sometimes punctate but is usually smooth. The guard is composed of prismatic layers, which are separated in

transverse section by thin, closely arranged septa, which become more widely separated with increased distance from the phragmacone. The apex of the cone-shaped alveolar cavity is subcentrally located in the adult forms but is central in young individuals. The species varies much in size but retains the same general form.

Dimensions: Length of specimen, 140 mm.; length of phragmacone, 50 mm.; diameter, 20 mm.

Geological horizon: This species occurs in great abundance in No. 13 of the section. It is found associated with *Pleuromya subcompressa*, *Astarte packardi*, *Pinna kingi*, *Goniomya montanaensis*, etc.

Locality: Freeze-out Hills, Wyoming. Black Hills, Dakota, and elsewhere.

Remarks: This is by far the most abundant species in the Jura of Wyoming. In certain outcrops in the Freeze-out Hills the slopes of the hills are so completely dotted with them as to leave scarcely a single square foot without one or more representatives. From these outcrops it is possible to gather bushels of them. Their persistence in the stratum in which they occur make it a good guide in the study of the stratigraphy. *B. skidgatensis* is undoubtedly a synonym of *B. densus*, as all of the forms figured by Meek have the same form as Whiteaves's species.

***Belemnites curtus*, n. sp.** Plate XXIX, figs. 4, 5; plate II, fig. 3.

Guard large size, thick, abruptly pointed, subquadrangular at the distal end, while it is more cylindrical toward the proximal portion. The point of the guard is extremely blunt. The guard substance is dense, dark colored, and of prismatic structure.

Dimensions: Length, 120 mm.; diameter, 30 mm.

Geological horizon: No. 13 of the section has furnished a few specimens of this species.

Locality: The Freeze-out Hills, of Wyoming.

Remarks: Such a radical difference in general form seems to exclude the possibility of this form belonging to *Belemnites densus*, while its symmetry would indicate that its difference of form was not due to an accident of growth.

This form was never figured by Meek under the name *B. densus*, but the form so described is longer and more slender. The latter I take to be the same as *B. skidgatensis* Whiteaves. This is one of the species which link the Jura of Wyoming with that of Queen Charlotte islands.

Asterias dubium Whitfield. Plate XXV, fig. 3.

A single imperfect specimen collected from the crinoidal sandstone horizon possesses characters very similar to those of the above-named species. The specimen is somewhat weathered, and, as a result, its

specific characters are difficult to determine. The arms are a fraction over an inch in length, and are elevated along the central portion. They are composed of small plates arranged longitudinally. The center of the body is marked by a depression which appears to be almost circular, although the margin is not entire, being more or less obliterated by weathering. In general shape the upper surface of the rays are subangular. The rays are not so curved as those in the specimen described by Whitfield*; it may be that the first is an older individual.

Geological horizon: The species occurs in a thin stratum of sandstone in the bluish shale of No. 15 of the section. It is found associated with *Pentacrinus astericus*, *Belemnites densus*, etc. The sandstone in which it occurs is fine-grained, laminated stone, which is free from impurities and varies much in degree of induration.

Locality: Freeze-out Hills, Wyoming; also reported from the Black Hills.

Remarks: The above species is not abundant in the Jurassic strata of the interior, as so far it has been reported only from the Jura of Wyoming. These forms, however, are not easily preserved, and the depositional conditions of the shallow Jurassic sea were never very favorable to their preservation.

Avicula macronotus Meek. Plate XXX, fig. 6.

Shell medium in size, arcuate, ornamented with two wings, the posterior one of which is much larger than the anterior one. The posterior wing bears a broad, shallow sinus, while the anterior wing is small and somewhat rounded. The hinge line is moderately long. The surface of the shell is ornamented with strong radiating plications or ribs, which are crossed by well marked lines of growth. These form, at the points of intersection, nodes which are prominent on the lower part of the shell but scarcely visible in the umbonal region. The umbonal region is the area of greatest convexity. The anterior margin of the shell projects slightly in the upper part so as to leave a faint sinus below the anterior wing. It curves obliquely backward to the basal border below, with which it forms an almost regular curve extending nearly to the posterior basal extremity. The last-named portion of the shell is also rounded. The beak is sharply pointed, shows a tendency to incurve, and is elevated above the cardinal line.

Dimensions: Length, 20 mm.; width, 12 mm.; height, 5 mm.

Geological horizon: This species occurs in the thin sandstone stratum of No. 15 of the section. It is found associated with *Asterias dubium*, *Pentacrinus astericus*, and *Belemnites densus*.

* Geology of the Black Hills.

Locality: Freeze-out Hills, Wyoming; also reported from the Black Hills.

Remarks: The form above described resembles very closely the northern European species, *Avicula tenuicostata*, but not the species *Avicula munsteri*, as suggested by Meek.*

The Atlantasaurus Fauna.

Aside from the huge reptilian remains for which the Atlantasaurus Beds are justly celebrated, it contains an interesting, although not abundant, invertebrate fauna. The forms represented are all well-known fresh-water types. Among them are species of Mollusca belonging to the genera *Unio* and *Cyprena*, and gastropods belonging to the genera *Valvata*, *Lioplacodes*, and *Viviparus*. These invertebrates have been found in the Black Hills, in the Freeze-out Hills, and in the Atlantasaurus Beds of southern Colorado.

The Potomac formation of the Atlantic coast, which was deposited under like conditions and has like lithological characteristics, also contains a similar fauna. The habitat of the Potomac fauna, however, were probably waters of a brackish nature.

The Wealden formation of England contains the greater part of the genera which occur in the Atlantasaurus Beds, and is doubtless of the same age. The two formations have similar lithological characters, and four of the genera — *Unio*, *Valvata*, *Planorbis*, and *Viviparus* — which are represented in the two formations by species having practically the same degree of development, are not known from older formations.

Lioplacodes veternus Meek. Plate XXXI, fig. 5.

Shell small, planorbicular, composed of three or four whorls lying in the same plane. The volutions are rounded, and increase rapidly in size. The position of the decreasing volutions form concavities on each side of the shell, the most prominent one being on the left side. The surface of the shell is smooth and the aperture is nearly circular, apparently, although the specimen is somewhat crushed.

Dimensions: Diameter, maximum, 8 mm.; diameter of outer whorl, 3 mm.

Geological horizon: No. 22 of the section furnished a number of these forms, while a few were collected from the clay of No. 21.

Locality: The Freeze-out Hills, Wyoming; also the Black Hills, Dakota.

Remarks: This specimen is much larger than that described by Meek, but as there appears to be no other essential difference it is probable that the latter is only a young individual.

This genus was first recognized in the Wealden of England, and

*Geology of the Upper Missouri.

has not been recognized in any older formations. It occurs here in apparently the same degree of development, and has not been recognized in any older rocks on this continent.

Unio willistoni, n. sp. Plate XXXI, fig. 10.

Shell medium size, broadly subelliptical but only slightly convex. The ventral border of the shell is nearly straight while the dorsal border is moderately convex. The posterior margin is sharply rounded; the anterior margin is subtriangular. The test is thick. The surface of the shell is ornamented by prominent concentric lines of growth. The convexity of the surface is slight and has its greatest prominence in the umbonal region. The ventral slope is short and abrupt while the dorsal slope is long.

Dimensions: Length, 50 mm.; width, 30 mm.; convexity, 5 mm.

Geological horizon: This species occurs in No. 22, associated with other non-marine forms.

Locality: The Freeze-out Hills, of Wyoming.

Remarks: The type specimen is a cast of a large individual, which is the largest specimen collected.

The genus *Unio* was first recognized in the Wealden of England, where it occurs in about the same degree of development as in the Atlantasaurus Beds. The appearance in these two formations of four genera, occurring for the first time and in practically the same degree of development, furnishes a strong argument in favor of their correlation.

Valvata leei, n. sp. Plate XXXI, figs. 1, 2, 3.

Shell small, composed of three volutions, which increase rapidly in size. The spire is depressed so that it does not equal more than one-half the body whorl at the aperture. The test is very thin. The volutions are subangular around the upper outer side, and flattened horizontally between the angle and the suture; ventricose on the outer and under sides. The suture line occupies a well-marked depression. The aperture is oval in shape. The surface is ornamented by prominent lines of growth.

Dimensions: Diameter through aperture, 13 mm.; diameter exclusive of outer whorl, 4 mm.; height of spire, less than 3 mm.; height of outer whorl at aperture, 4 mm.

Geological horizon: No. 22 of the section, where it is associated with species of *Unio* and *Lioplacodes*.

Locality: The Freeze-out Hills, Wyoming.

Remarks: The type specimen was collected from the above stratum by Mr. W. T. Lee, in whose honor it is named. It is not as large a shell as *Valvata scribda*, described by Meek, from Dakota, but it differs more essentially in the character of its spire, which is much

more elevated in Meek's specimen. In respect to other characters the forms are closely analogous.

Unio knighti, n. sp. Plate XXXI, figs. 7, 9.

Shell small, long, narrow, very convex. The hinge line is long and straight. The dorsal border is nearly straight and the dorsal slope very abrupt. The ventral border is slightly convex and the slope not so abrupt as the dorsal. The posterior margin is sharply rounded. The beaks are unknown. The shell surface slopes gradually from the area of greatest convexity to the posterior margin and more abruptly toward the anterior margin. The surface of the shell is ornamented by regularly arranged concentric lines of growth.

Dimensions: Length, 40 mm.; width, 12 mm.; convexity, 12 mm.

Geological horizon: This form occurs in No. 22 of the section, where it is associated with *Unio willistoni, Valvata leei, Lioplacodes veternus*, etc.

Locality: The Freeze-out Hills, Wyoming; also Black Hills, Dakota.

Remarks: This form was collected from the non-marine Jura in the above-named horizon, and has been named in honor of Prof. Wilbur C. Knight, who in company with Prof. E. H. Barbour first discovered this fossil-bearing stratum.

Unio baileyi, n. sp. Plate XXXI, figs. 4, 6, 8, 11.

Shell medium size, convex, elliptical in general outline. The hinge line is straight and of moderate length. The beaks are slightly incurved and the umbonal region is somewhat flattened. The dorsal border is convex, as is also the ventral. The posterior and the anterior borders are nearly equally curved. The test is thick. The ventral slope is abruptly rounded while the dorsal is more broadly convex. The surface ornamentation consists of well-marked lines of growth concentrically arranged.

Dimensions: Length, 32 mm.; width, 23 mm.; convexity, 7 mm.

Geological horizon: This species was collected from the fossil-bearing stratum, No. 22 of the section, in which it occurs associated with other non-marine forms already mentioned.

Locality: The Freeze-out Hills, of Wyoming.

Remarks: A comparison of the *Unios* here described with those from the Wealden of England will be especially interesting. The *Unios* from the two formations have practically the same degree of development and are not known from any older rocks on either continent.

THE SPERMATOGONIAL DIVISIONS IN BRACHYSTOLA MAGNA.

BY WALTER S. SUTTON.

With Plates XXXII, XXXIII, XXXIV, XXXV.

INTRODUCTION.

THE material for this paper was collected in the summer of 1899, in Russell county, Kansas, together with testes from about thirty-five other species of Acrididæ, for the purpose of making a study of the spermatocyte divisions. However, before the material was prepared, McClung's paper on "The Spermatocyte Divisions of the Acrididæ" appeared, and as, on examination of my material, I found his observations and conclusions to be generally true, I decided to leave that subject for a comparative study in a later paper, and to restrict this publication to the spermatogonial divisions (with special attention to the chromatic elements)—a field which seems to have been very generally neglected, and for which *Brachystola* is especially favorable.

I have been fortunate enough to find in this material two structures or conditions which, so far as I know, have never before been described in germ-cells. One of these is the presence, in a certain stage, of a distinct membrane around each chromosome and the absence of any general nuclear membrane (figs. 12, 13, 14, 30, 31, 32, A, and G), and the other a vesicular arrangement of the chromatin in one of the chromosomes. (Figs. 31, 33, 34, 35, F, and J.) *Brachystola* has also shown itself a favorable object for the solution of the problem of the origin of the spermatocysts.

I wish to express here my gratitude to Prof. C. E. McClung, for many valuable suggestions and for other assistance in the prosecution of this work, and in the making of the photomicrographs given

herewith. My thanks are also due to Prof. S. J. Hunter, for assistance in the determination of the insects from which the material was taken.

MATERIAL.

Brachystola magna, commonly known as the "lubber grasshopper of the plains," is one of the largest known species of locust. It is clumsy and ungainly, having powerfully developed legs and the most rudimentary wings.

In distribution, the insect is general—though more or less rare—over all the western plains. The adults put in their appearance about the first of July, and at this time the testes are found to contain spermatogonia, spermatocytes, spermatids, and spermatozoa, in order, from the blind ends of the follicles to the *vas deferens*.

The testis is unpaired. The follicles, of which there is a large number, are comparatively short and thick, and do not lie approximately parallel to one another and to the long axis of the animal, as is the case in many other Acrididæ, but project upward and backward from the rhacis to which they are attached, and diverge strongly from one another.

The young testis is smaller than the mature one (which attains the size of a large pea), is pure white in color, and of a firm consistency. In the older organs the white color gives way to a reddish yellow, and the testis becomes soft.

The proximal portion of each follicle, as it is evacuated of spermatozoa, becomes constricted, and thus the follicle loses its earlier cylindrical form.

Of the origin of the acridian testis nothing has been written, and, as my material was too old for a thorough study of the subject, I will leave the question until a later time. However, in the testes of nymphs of *Arphia*, taken about the time of the first molt, I have seen a longitudinal rhacis having follicles attached to it, as in the adult organ, both rhacis and follicles being so small that in a longisection not more than four of the primary spermatogonia with which they are filled could be seen abreast; that is, the diameter of the follicle and of the rhacis was about four times that of a cell. The testis of *Brachystola* probably passes through a similar stage. The primary spermatogonia of these follicles divide as such until the testis has attained a considerable size, when they go over into secondary spermotogonia, as described later, each one at the transition giving rise to a spermatocyst. This change begins at the proximal end of the follicle and, proceeding fastest along the follicular membrane, extends as a wave toward the distal end, the riper cysts being forced toward the *vas deferens* by the growth of those beyond. The small

cysts of the earlier stages are, therefore, found at the blind end of the follicle, and the mature spermatozoa near the *vas deferens*, the intermediate stages lying between. Ordinarily all the cells of a cyst are in the same phase of development at any given time.

Excepting the youngest secondary spermatogonia, any cyst will present a later stage than its neighbor which lies farther from the *vas deferens*, but it does not follow that successive cysts represent consecutive stages; for, as will be shown later, each cyst develops independently, but at about the same speed as the rest, so that whether or not adjacent cysts show consecutive stages depends mostly upon the relative time of the division of the primary spermatogonia from which they arose. We may, therefore, find several cysts in the same stage; or, between the stages of adjacent cysts, a considerable gap may exist.

The mature follicular membrane is composed of two layers, between which may be seen numerous, deeply staining, flattened nuclei. (*n*, fig. 1.)

FIXING AND STAINING METHODS.

Several fixing methods were used, but by far the most favorable proved to be Flemming's chrom-osmium-acetic mixture. The testes were hardened in this from four to twenty-four hours, after which they were carried up through different grades of alcohol to seventy per cent., where they remained until it was desired to imbed and section them.

All material was stained in section. Of the various stains tried, Heidenhain's iron-hæmatoxylin proved the best for nearly every purpose. The sections were placed in a mordant of four per cent. iron alum for about fourteen hours, and then, after thorough washing, stained about ten hours in one-half per cent. hæmatoxylin. They were then washed again, and finally differentiated under the microscope in the same fluid used for the mordant.

Flemming's three-color method proved useful in the study of the behavior of the accessory chromosome. This was used as follows: The sections were placed in Zwaardemaker's safranin for from forty-five minutes to two hours: the excess of this was washed out in ninety-five per cent. alcohol, and they were immersed for ten minutes in a half-saturated aqueous solution of gentian violet. This was washed out with water and the sections treated for three seconds with orange G., after which the stain was differentiated with ninety-five per cent. alcohol and clove oil. Kernschwarz and safranin also produce a very good stain for this work.

Sections were cut $6\frac{2}{3}$ microns thick and fixed to the slide with Mayer's albumen water of a strength of two drops of the albumen to an ounce of distilled water.

TERMINOLOGY.

The terminology used in this paper will be made to conform as nearly as the case allows to that in general use. The terms spermatogonia, spermatocyte, spermatid and spermatozoön will be used with their usual significance. In addition to the cells ordinarily indicated by these names, others will require consideration which are analogous to the "sex sells" of Voight and Semper, the "primordial metrocyte" of Biondi, the "germinal cells" of Balfour and von Ebner, the "primitive male ovule" of St. George and others, the "grosse Spermatogonien" of Meves, and the "primary spermatogonia" of McGregor. The latter term, which indeed I had considered before the appearance of McGregor's paper, is very suitable for these cells, and, in connection with the name "secondary spermatogonia," for the derivative cells occurring in cysts (as also employed by the same author), will be used in this paper.

The different phases of a single cycle of division will be designated in the usual way, as prophases, metaphase, anaphases, and telophases, and, in order to avoid the confusion which sometimes arises from the slightly different ground which various authors are accustomed to cover by these terms, I will define their extension as used by me for this object.

The moment when the chromatin of the daughter-cell has reached the greatest degree of diffusion, and from which it commences to take on the form of a spireme, will be regarded as the dividing line between the telophase of one generation and the prophase of the next. This is the logical place for the division line between cycles, since the disintegration of the chromosomes of the daughter-cell is to be regarded as a mere restoration of the metabolic condition of the chromatin after the necessary assumption of the condensed form for the purpose of division. The prophases will include all conditions of the cell from the point named to the metaphase, in reference to which there is no uncertainty. The anaphases will cover all stages from the beginning of the separation of the chromosomes at the equatorial plate to their arrival at their destination about their respective centrosomes. The telophases will begin at this point and extend to the end of the cycle as already designated.

As to the extension of the different generations of testicular cells, only two will need to be defined, namely, the primary and the secondary spermatogonia.

Of the former I have seen but one generation in *Brachystola*, as I was able to obtain only adult material. However, in the formation of the testes in *Arphia*, I have observed the earliest follicles to be composed exclusively of them, and the growth of the follicles, and consequently of the testis, to be accomplished by their mitotic division.

The early divisions which result in an increased number of primary spermatogonia I will designate as multiplication divisions, and the last one, which results in secondary spermatogonia, as the transformation division. It is probable that the multiplication divisions cease and a resting stage ensues before any of the cells enter upon the transformation division.

The chief distinguishing characteristics of the secondary spermatogonia are the presence of a cyst membrane around the groups in which they are arranged, and the appearance of the distinct chromosomic vesicles in place of the common nuclear membrane. The two-cell cyst, therefore, marks the transformation.

The transition of the secondary spermatogonia into spermatocytes occurs at the end of the last telophase, preceding the growth period (synaptic stage of Moore), which latter is readily recognized by the much-increased size of the cells, the large, clear vesicular nucleus with its spireme, and by the characteristic position and shape of one of its chromatic elements (the accessory chromosome).

This element has been frequently noted by investigators and in a few cases more or less carefully described, but is nearly always regarded as a nucleolus. Last year, however, McClung, in a paper on "A Peculiar Nuclear Element in the Male Reproductive Cells of Insects," called attention to its unusual behavior and staining reactions, and demonstrated the necessity for regarding it as an accessory chromosome. His investigations, in the main, were on the spermatocytes and spermatids, but my own upon the spermatogonia only serve to strengthen his conclusions. The behavior of this element in the spermatogonial divisions of *Brachystola* is such that to call it a nucleolus would be ridiculous in the extreme. Therefore, since the name "accessory chromosome," provisionally used by McClung, has proven consistent with all the phases of the element yet seen by me, it will be retained in this paper. Paulmier, also, in a very recent paper on "The Spermatogenesis of *Anasa tristis*," expresses his opinion that this element is not a nucleolus but a modified chromosome, which he designates as the "small chromosome." The membranous investment of the whole follicle will be known as the follicular wall, and that of the separate spermatocysts as cyst membranes (Cystenhaut of St. George).

OBSERVATIONS.

As already mentioned, spermatogonia are of two kinds, primary and secondary. The primary spermatogonia appear in the follicle at its earliest beginning and by their multiplication, by mitotic division, produce a considerable increase in the size of the follicles and consequently of the testis. They are variable in size, are closely packed

together, and have relatively little cytoplasm. (Fig. D.) The nuclei are large, oval, smooth in contour, and poorer in chromatin than the secondary variety (fig. D); and, in all stages, the nuclear membrane is represented by a single vesicle instead of by one for each chromosome, as in the secondary spermatogonia.

In the testis of the adult insect, the primary spermatogonia are comparatively rare, having for the most part already been transformed into secondary spermatogonia. In a few follicles, however, I have been able to find these in larger or smaller numbers. Where they are numerous, they lie around the axis of the follicle a short distance from its blind end and sometimes also in a single layer at the extremity (fig. 1), indicating that development began, not at the center of the follicle, as we might expect, but at the periphery next to the follicular wall.

Where the primary spermatogonia are few they lie in the interspaces between spermatocysts, and some of them form the "Cystenkernen" of St. George. It would hardly be surmised that the nuclei of the cyst walls are formed from the same source as the germ-cells themselves, but nevertheless there is strong evidence to show that such is the case.

In the first place, the primary spermatogonia near the cyst walls cannot be distinguished by form or staining qualities from those lying in the interior of masses of their kind. In the second place, even as far up the follicle as the zones of spermatocytes and spermatids, no flat nuclei are to be seen in the cyst walls, as described by a number of authors. Instead, in the angles between cysts, where they meet near the median line of the follicle, as well as where they are contiguous with the follicular wall, may be seen cells with nuclei like that of fig. 2 filling the spaces. (Fig. 41.) As I have said, these are the only nuclei of the cyst walls in this portion of the testis. Now in some cases, where masses of primary spermatogonia are found in the blind end of the follicles, each nucleus will be seen to be exactly similar in shape, staining reaction and arrangement of chromatin to those just mentioned. The latter similarity, of course, is found only when the cells are in the resting condition, for, immediately on the commencement of preparations for division, this likeness in arrangement of chromatic substance is lost.

Where masses of primary spermatogonia in the resting stage or early prophases are found, they appear like a quantity of nuclei, sometimes almost devoid of cytoplasm, enveloped in a matrix of stroma. On the edges of these masses, where they come in contact with cysts of secondary spermatogonia, the cyst walls seem to be continuous with the cell-walls or enveloping stroma of the nearest

primary spermatogonia, giving the appearance of splitting and surrounding the latter.

The primary spermatogonia preparing for division can hardly be said to enter directly upon a prophase, for that term as I have used it implies the presence of a spireme. I do not regard the resting stage as belonging in the direct line of division of the cell, but rather as a special condition into which the chromatin enters for the purpose of preparing for the rapid divisions which follow, or, as in the case of those found between cysts of older cells, to secrete matter for the maintenance and extension of the cyst walls.

The chromatin of the resting-cell is arranged in flakes or patches around the periphery of the nucleus, and these are connected with one another by a few linin fibers. (Fig. 2.) As the cell prepares to enter upon the prophases, a number of changes are to be seen; the flakes of chromatin begin to be less clearly defined (fig. 3), linin fibers become more numerous, and slowly the cell acquires more cytoplasm. These changes proceed until the chromatin of the nucleus has assumed a reticular arrangement similar to that of fig. 4, after which it may fairly be said to enter upon the prophases.

One of the earliest of these is shown in fig. 5, where the chromomeres are arranged in several (probably the chromosomic number) moniliform threads, lying for the most part against the nuclear membrane; and the linin fibers are either all included in this thread, or are now so very minute as to escape observation. Fig. 6 shows another step. The chromatic threads still lie on the periphery, but they have grown shorter and thicker, and there is no longer any doubt that each corresponds to a future chromosome. Here the linin has again come into evidence.

About this time a clearly defined longitudinal split appears in the threads (fig. 7), and the shortening and thickening of the segments continues until we get the condition shown in fig. 8 — a number of short, thick, longitudinally split chromosomes almost ready for division. These now assume the form of short double rods, smooth in contour and apparently homogeneous in structure; the nuclear membrane is dissolved, the spindle appears, the chromosomes take their place in the equatorial plate, and the cell is in metaphase. (Figs. 9 and 10.)

Primary spermatogonia in any other phases than the resting stage or early prophase are, in my material, extremely rare, and in the few late prophases I have seen there is nothing to throw light upon the origin of the centrosomes. I have seen the latter only in the metaphase, where they are clear and sharp but very small.

The next stage which came to my notice is shown in fig. 11. Here

the chromosomes are grouped about their respective centrosomes, and the connecting fibers traverse about the same ellipsoidal course as did the fibers of the metaphase. The absence of granular cytoplasm in this case is probably accidental.

At this point I again find a gap in the series, the next stage represented being a cyst containing two cells in the stage shown in fig. 13, *i. e.*, cells whose nuclei are composed of a number of pockets containing chromatin in a diffused condition. This is the phase which I have designated as between telophase and prophase. The two cells of this stage and generation which I did find, however, differed from cells of the same stage in later generations in no essential particulars. They did not show the accessory chromosome nor did the few cells of the second generation which I was able to find, probably on account of the position of the element in the cell. It is therefore impossible to state whether this interesting structure appears in the first or in a slightly later division. There is, however, only one explanation for the partitioned or lobulated condition of the nucleus, and that is the course which brings about the same condition in later generations. Briefly, it is this: Immediately after the formation of the partition wall between the daughter-cells, the chromosomes begin to disintegrate. They lose their homogeneous appearance and become granular, and, at the same time, there is formed about each one a distinct membrane. (A cross-section of such a cell is shown in fig. 12.) This condition of separate chromosomic vesicles, however, does not last long, as the partition walls between them are soon dissolved where they come in contact with each other at their polar ends, so as to produce the peculiar glove-like effect of fig. 30.

The condition of fig. 13, which represents a cross-section of the "fingers" of the "glove," is then reached by a simple separation of the chromomeres.

THE SECONDARY SPERMATOGONIA.

When, in the telophase of the transformation division of a primary spermatogonium, the chromatin has reached the utmost limit of diffusion, it begins to take on the form of an extremely fine convoluted or spiral thread in each of the diverticula of the nucleus.

This is the first of the prophases of the secondary spermatogonia as well as the beginning of a cyst, for a common membrane may now be seen about these two cells, which envelops their descendants throughout their divisions and marks them off from other cysts.

There are, however, a few cases in my preparations which seem to be exceptions to this rule. Although it is almost invariably the case that all the cells of a cyst are in the same, or very nearly the same, stage of development, occasionally a small cyst is found which shows

the cells upon one side, in the metaphase, for instance, and those on the other side in a middle or late telophase, and nowhere any intermediate stages. Such an instance is shown in fig. G, and here, as it generally happens in these cases, may be seen in the middle, between the two kinds of cells, one (fig. 40) which, by its poverty of chromatin and the peculiar brownish cast of the same, as well as by the cloudy aspect of its cytoplasm, shows itself to be degenerating.

These degenerating cells are primary spermatogonia, and the reason for their presence here and for their degeneration is probably as follows: Two neighboring primary spermatogonia pass through the transformation division and reach, say, the two- or four-cell stage, and at this time have between them another primary spermatogonium. The next division greatly increases the volume of these two cysts and their walls meet around the cell between them on all sides. Then, for some reason, the contiguous portions of the cyst membranes are resorbed, the two cysts become united, and the cell in question is imprisoned in the middle of what is now a single cyst. There, being cut off from the structures from which it has been wont to derive its nourishment, it rapidly breaks down and disappears, and is never found in a cyst of more than twenty cells.

In cases of this kind, where, on account of their different origin, the cells of a cyst represent two different stages of development, the tendency is for the one set to go slower or the other faster, so that in the course of a few divisions they get in step, as it were, with one another.

This union of young cysts accounts for the fact that occasionally we find, in the zone of spermatocytes, cysts of exceptionally large size, while in general they are of about equal volume, indicating a fixed number of spermatogonial divisions.

The question now arises, How from a single cell and its cell membrane do we get two cells each with its cytotheca, and in addition a cyst membrane containing both these daughter-cells? The solution seems to be this: In the early stages there is between and among the primary spermatogonia a membranous intercellular substance with which they are in intimate relation, as shown by the fact that they never shrink away from it. As development proceeds, however, the close relation between the cell and intercellular substance is lost, and in the metaphase (as was the case with the cell shown in fig. 10 and also in fig. D) we sometimes find the cell membrane separated in places from its capsule. (*a*, fig. D.)

It now only remains for the separation to become complete. When the two-cell stage is reached the spermatogonia and the cyst which contains them are independent structures. As the number of cells

within the cyst increases by division, the cyst membrane, obviously, becomes more and more extended, the material for this increase being furnished by those primary spermatogonia which still remain in the resting condition, one or more being always found in relation with each cyst, either in the axis of the follicle or between the cyst and the follicle wall.

To return now to the developing cell; the spiremes of the prophase attain, by a process of shortening and thickening, the form of short, heavy, rough-contoured spiral threads (fig. 19), which split longitudinally. These assume a form similar to that of the chromosomes in the metaphase already described and divide along the lines marked out in the prophase, giving rise to two cells each, and consequently to a cyst of four cells.

It is not until the eight- or sixteen-cell stage that I am able, in my preparations, to find all the stages, but such as I do find in the few smaller cysts which I have seen would indicate no difference between the early and late spermatogonial divisions.

These I will describe in detail, beginning with the anaphases, as I have seen them in the later generations, and as I believe them to commence after the metaphase of the primary spermatogonia.

At the beginning of the anaphase, the chromosomes are in the form of double rods lying in the equatorial plate, perpendicular to the axis of the cell and attached by their central ends to the spindle fibers. (Figs. 22, 23.)

The separation marking the commencement of these phases begins at the central ends of the chromosomes, producing a circle of V-shaped figures with their apices outward. The two halves remain connected at their outer ends until the apex of the "V" has been drawn down into line with the limbs, when they separate and the two halves travel through an elliptical course to their respective centrosomes (fig. 25), stretching out between them the connecting fibers, which at first preserve the ellipsoidal shape of the spindle figure, but soon begin to draw together in the middle so as to form first a cylinder and then a hyperboloid. (Figs. 26 and 27.) During this time the cell-wall has constricted across and we now have two daughter-cells connected by the persisting spindle. Where this spindle penetrates the cell-wall there is developed on each of its fibers a slight enlargement which stains rather deeply. (Fig. 27.)

Many authors describe these connecting fibers as being arranged in two cylinders, one within the other, and distinguish them by the names of spindle fibers and mantle fibers, respectively. In this object, however, as shown by fig. 28, almost all the fibers are confined to the mantle, a very few being irregularly disposed within.

When the cells reach this stage they seem to have a tendency to roll upon one another, so that the ends of the chromosomes of the one no longer point toward those of the other (figs. 29 and 31), and the spindle, instead of holding its place in the center of the partition wall, comes to lie at one side. (Fig. J, *s*.)

Almost immediately after the chromosomes reach the centrosome they begin to change, finally losing their homogeneous appearance and becoming rough in contour, while around each is formed a distinct membrane in place of a common nuclear membrane enclosing all. In each chromosome, the separation of the chromomeres, for such is the nature of the change, sometimes results in a hollow space in the middle which makes it appear under the microscope as though longitudinally split. (Figs. 30 and 34.) In all but one, this hollowing process proceeds but a short time until it is followed by a general diffusion of the chromatin within the compartments, which have now become intercommunicating by a resorption of the contiguous portions of their walls at the polar end of the cell, giving the glove-shaped nucleus already mentioned. (Figs. 30 and 31.) One of the chromosomes, which can occasionally be distinguished from the others in the metaphase or anaphases by its rougher contour and greater length (fig. 24), does not join its cavity with that of the others, but remains separate, and further makes itself conspicuous by depositing its chromatin upon its vesicular membrane. (Figs. 31, 33, 34, and 35.) This is the accessory chromosome, and in this condition might be spoken of as the vesicular chromosome. Except after the last spermatogonial division, this element remains shut up in its vesicle until the following metaphase, whereas the fusion of the other vesicles may, in rare cases, proceed so far as to reduce the "fingers" of the "glove" to a set of shallow pockets in the surface of the nuclear membrane. (Fig. 34.)

The chromatin of the vesicular chromosome, after remaining for some time at the periphery, again recedes, and accumulates at the center of the vesicle in a form like that shown in fig. 36, which was drawn from a similar stage in the last division. Fig. 13 represents a cross-section of the "fingers" of the nucleus at this time, the dense body at the right being the accessory chromosome. This is the end of the telophases, and here the cell enters upon the prophases of a new generation. The chromatin in the common nuclear membrane begins to take on the form of a number of fine spiremes, while the accessory chromosome assumes the irregular shape shown in fig. 15, *a*.

The spiremes of the nuclear space become shorter and thicker, which process is accompanied by a greater or less resorption of the partitions between the fingers or pockets of the nucleus (figs. 15 and 19), and the accessory chromosome grows gradually smoother and

more regular in outline, soon becoming of uniform diameter and often twisted like a rope. (Fig. 16; fig. A, *x*.) About this time the ordinary chromosomes show a tendency to lose their spiral form (figs. 17, 18, 19, and 39), and in some of them may be seen a distinct longitudinal split.

Near the stage shown in fig. 16, there may be seen, close to that portion of the nuclear wall which faces the greatest mass of cytoplasm, two extremely minute but deeply stained centrosomes, each with its radiate arrangement of the cytoplasm and joined together by a very small centrodesmus. These move wider apart (fig. 39) as the chromatic threads assume more and more the form of chromosomes, and soon come to lie diametrically opposite one another. This moment is marked by the disappearance of the nuclear membrane but not always of that of the accessory chromosome (fig. 21), which now has the form of a rough double rod (fig. 15), or, as often, of a two-strand rope (fig. 21*a*). I have noticed a splitting of the accessory chromosome at a stage as early as that shown in fig. 16, in which case, however, it is impossible to determine its condition.

Soon the chromosomes, including the accessory, assuming the form of short, thick, straight or slightly curved double rods, take their places in a radial position in the equatorial plate and the central end of each becomes attached by several fibers to each of the centrosomes. (Figs. 22 and 23.)

We have now completed the cycle of the ordinary spermatogonial division. The telophases of the last division, however, differ from those of the others, as we would naturally expect, in preparation for the growth stage of the spermatocyte. This difference consists in the reduction, in the late telophases, of the sacculated nucleus to a mere irregular vesicle, which finally becomes smooth in contour; and in the regular diffusion of the chromatin throughout the nuclear space. The accessory chromosome becomes more and more condensed, and its membrane, closely applied to that of the nucleus, still encloses it at the time of the change to the spermatocyte.

Fig. 38 represents an early spermatocyte prophase in which the hollow center of the vesicular stage of the assessory chromosome seems to be not entirely obliterated.

DISCUSSION AND COMPARISON OF LITERATURE.

I. *The Origin of the Spermatocysts.*—The occurrence of the sperm-cells of animals in groups or spermatocysts has been recognized and mentioned by investigators upon the most various forms since it was first noted by St. George in the *Amphibia*, in 1876. Few authors, however, have attempted any explanation of their origin, or even a description of their structure, many seeming to take their

presence as a matter of course, and merely alluding to them in description of other elements of the testis.

St. George, in 1876, described these structures in *Rana temporaria*. He found the cyst membranes of each group of spermatogonia to lie within, though generally not mechanically continuous with, other membranous compartments which were to be distinguished from the cyst membrane only by careful observation. These latter are continuous with the walls of the canal and with one another, and serve to support the cysts. Each membrane has its nuclei, which are easily distinguished from each other by the arrangement of their chromatin. As to the origin of the cysts, his opinion is that a single early cell is surrounded by other cells, which latter become continuous with one another, and, losing their protoplasm to a large degree, gradually assume the form of a membrane, while the single cell thus imprisoned gives rise by constriction of its nucleus to the cells of the mature cyst.

Henking, in 1891 (*Pyrrhocoris*), first mentions the cyst membrane in describing groups of cells of considerable size. In older membranes, he saw large nuclei resembling those of connective tissue cells, each having about it a layer of cytoplasm. He noted that all the cells of a given cyst are in approximately the same stage of division and that the equatorial plates of the division figures were uniformly tangential to the circumference of the cyst as seen in section. He also mentions groups of cells lying in circles about differently constructed central cells, which latter are easily distinguished by their large size and poverty of chromatin. This condition probably corresponds to that shown in fig. G, and, if so, argues an origin of cysts similar to that in *Brachystola*.

Vom Rath, in 1892 (*Gryllotalpa*), says nothing of the presence of cysts in his object, but the conical shape of certain spermatogonia figured in his plates is a strong indication of their presence.

Toyama, 1894 (*Bombyx*), speaks of the arrangement of the early conical cells with their apices attached to the processes of supporting cells. He describes the sperm- cells as grouped in cysts, and notes the synchronous division of the cells of each group.

Montgomery, in 1898 (*Pentatoma*), goes into the subject more in detail. After describing the six follicles of which each testis is composed, he says: "Each follicle is bounded by a sheath of connective tissue formed of interlacing, branched, connective tissue cells, some of which also penetrate the interior of the follicles. These branching processes of these connective tissue cells serve to demarcate more or less spherical groups of cells, the spermatocysts of v. la Vallette St. George." He has not seen the formatian of the cysts, but thinks it

probable that in the embryonic testis there is a network of connective tissue, in each mesh of which is contained "a single spermatogonium. or at least only a small number of spermatogonia." The cysts are then built up by the division of these cells, the cyst membrane being formed by the extension of the connective tissue investment. The maturer cysts are forced towards the *vas deferens* by the growth of the younger ones beyond. This supposed origin of the cyst in *Pentatoma* differs from the process as seen in *Brachystola* mainly in the implied difference in origin in Montgomery's description between the sperm-cells and those of the cyst walls.

Paulmier, 1899, states distinctly that in his material (*Anasa*) the spermatogonia occur at the blind end of the follicle singly or in groups not yet surrounded by a membrane. After a certain number of divisions, each group becomes surrounded by a connective tissue wall continuous with the lining of the follicle, and the cells assume the conical shape noted by Henking, Montgomery, and others, and figured by vom Rath.

McGregor, 1899 (*Amphiuma*), gives the presence of the cyst membrane about groups of secondary spermatogonia as one of the chief points of distinction between them and their predecessors, the primary spermatogonia. He notes the conical form of the cells of the younger groups and the fact that the secondary spermatogonia arise from the primary, but has nothing to say in regard to the number of primary spermatogonia taking part in the formation of a single cyst.

My own observations correspond, with more or less exactness, to something in each of these descriptions, though in many cases they present radical differences.

First, I find primary spermatogonia and secondary spermatogonia as McGregor does, but in *Brachystola* the primary spermatogonia do not divide amitotically, as he reports them for *Amphiuma*.

Second, the primary spermatogonia change to secondary spermatogonia, but a cyst is formed and a cyst membrane appears even in the two-cell stage; the latter being sometimes indicated in metaphase of the transformation division. (Fig. D, *a*.)

Third, the cyst membranes have nuclei, as reported by many, but they are identical with those of the resting primary spermatogonia.

Fourth, the cells in the young cyst assume a roughly pyramidal shape, as described by most authors, and tend to divide tangentially to the periphery of the cyst, as described by Henking; also, except in special cases, all the cells of a cyst divide almost simultaneously.

Fifth, occasionally a different sort of cell is seen in the middle of a young cyst of secondary spermatogonia, as described by Henking.

Sixth, the number of divisions of the secondary spermatogonia

seems to be constant, as intimated by Paulmier and McGregor. The number is probably seven, which would give 256 cells to the cyst of early spermatocytes, since secondary spermatogonia first appear in pairs as a result of the last division of a primary spermatogonium.

Seventh, the method of origin, as already described for this object, would argue against any attachment of the cysts to the walls of the follicles, as described by St. George and as suggested by Montgomery.

II. *The Accessory Chromosome.*—It has long been customary with observers to classify all the solid elements of the cell nucleus under three heads, viz.: Chromosomes, fibers of various kinds, and nucleoli.

The first two have been restricted to similar structures in the different forms, so that in regard to them no great confusion has arisen; but in regard to the latter such is not the case. The term "nucleolus" has had to serve for everything not falling directly under the other heads, in the opinion of the investigator; and truly it has, with a greater or less degree of efficiency, covered a multitude of errors. The most divergent bodies have been included under the same term, regardless of behavior, staining reaction, or, in fact, of anything else.

One of these much-neglected elements is that which in this paper I have called (after McClung) the "accessory chromosome." This most interesting structure, which I have reason to believe present in the sperm-cells of all insects, has been noted by a number of authors as behaving differently from the ordinary nucleolus, and has been variously designated as "nucleolus," "secondary nucleolus," "chromatin nucleolus," and recently, by Paulmier, as the "small chromosome."

It is most conspicuous in the growth stage of the spermatocyte, and consequently has been more frequently noted here than in the spermatogonia.

In *Brachystola*, the accessory chromosome appears probably in the first, and certainly in the third, secondary spermatogonial division, and goes through precisely the same changes in each cycle up to the last.

It may occasionally be distinguished from the other chromosomes in the metaphase and anaphases by its granularity and greater length, though it always divides like the others, and in the actual process of division, as a rule, is indistinguishable from them. In the telephase it constructs its own membrane just as do the others, but soon becomes sharply contrasted with them by the deposition of its chromatin in a diffused condition upon the inner surface of its vesicle (vesicular chromosome), and also by the fact that from this point to the following metaphase the cavity of its vesicle remains distinct from that formed by the junction of all the others. In these stages the vesicle of the accessory chromosome may lie on any portion of the nuclear

membrane proper; in some cases occupying a position between the "fingers" or sacculations of it (fig. 34). This vesicular stage is of comparatively long duration, and is followed by a receding of the chomomeres from the membrane to form a chromatic rod, first loose, rough, and granular, but gradually growing more slender and compact, and often becoming twisted (fig. 16). It also betrays a longitudinal split at a stage later than that at which a similar occurrence is observable in the ordinary chromosomes.

From the middle prophases to the telophases, its conduct is so similar to that of the other chromosomes that it would hardly be an error to speak of the cells of these stages as having two nuclei, one having a single chromosome and the other a large number, the small nucleus always lagging slightly behind the large one. This lagging of the accessory chromosome is nicely shown in fig. 21, already alluded to, where in a stage just before the metaphase the nuclear membrane is seen to be dissolved while that of the body in question is still intact.

In the last or transformation division of the secondary spermatogonia, some differences are noticeable in the behavior of the element under consideration. The vesicular stage seems to be of slightly longer duration, and while, after its close, the same condensation of the chromatin takes place, no longitudinal split appears until the late prophases or "ring stage" of the spermatocyte; and in the course of the earlier prophases of the growth period its vesicle gradually becomes fused with the nuclear membrane, its outer half completing the smooth contour of the latter, while its inner portion projects into the nuclear cavity. In this stage it has the appearance of an irregular vesicle filled with a homogeneous, darkly staining liquid or semiliquid body, suspended within the membrane of the nucleus. Later it again becomes granular, and in the first spermatocyte division divides as it did in the spermatogonia.

The resting stage of this element, as shown by its staining violet with Flemming's three-color stain, is what I have called the vesicular stage, and this only, since at all other times it stains a bright red. The absence of the formation of a spireme at any stage in the development of this element is paralleled by Henking's description of the normal process in all the chromosomes in the spermatogonia of *Pyrrhocoris*. He says: "Wenn die jungen Hodenzellen sich theilen wollen, so bekommt der Kern ein anderes Aussehen. Vorher durchweg dunkel (bei Behandlung-mit Flemming's Flüssigkeit) wird er nun licht, indem er sich aufbläht und zwischen die sich ebenfalls nicht unerheblich vergrössernden Chromatinkörner eine helle Substanz einlagert. . . . Das Chromatin hat sich in getrennten, im Allgemeinen ziemlich gleich weit von einander abstehenden etwa kugeligen Körnern angehäuft."

This being the case, it is not remarkable that Henking should have passed over a body which, in his material, probably very closely resembled the other chromosomes. In the growth stage, however, he describes it (under the name *nucleolus*) in a way which makes its equivalence to the accessory chromosome of *Brachystola* unmistakable. So far as I have been able to discover, Henking is the first to describe or figure this element.

Vom Rath, 1892, probably saw the accessory chromosome in *Gryllotalpa*, but his mention of it is so brief and vague that we can only surmise as to its identity with the structure so prominent in the Orthoptera. His only description of it is this, taken from his account of the maturation period: "Ein Nucleolus ist bis in dies Stadium deutlich wahrnehmbar geblieben, während ein zweiter völlig unsichtbar geworden ist. So viel steht fest, dass die Nucleoli an dem Aufbau des Chromatischen Fadens, keinen directen Antheil nehmen."

Wilcox, 1895, in *Caloptenus*, figures the accessory chromosome (fig. 111) in the spireme, stage of the spermatocyte, where I have seen it plainly in the same material, but makes no reference to its presence in the spermatogonia, unless the following statement should refer to it: "In fig. 106 there is a body (nucleolus?) which seems to have recently divided."

Moore, 1895, describes in *Elasmobranchs* the appearance of a "secondary nucleolus" surrounded by its vacuole at the beginning of the second spermatogenetic period (growth stage of the spermatocyte). This is the stage in which the accessory chromosome is most prominent in insects, and it is probable that Moore's discovery in the fishes corresponds to it. Another nucleolus is also present. Of the two he says: "These two peculiar forms are always to be found after the transition from the first to the second spermatogenetic period, and throughout all the generations of the latter." In his figures the "secondary nucleolus" has decidedly the appearance of the accessory chromosome of insects.

Julian Wagner, 1896, describes for the spiders a structure which, from its behavior in the first spermatocyte division, is certainly very like the accessory chromosome. He made no study of the spermatogonia.

Montgomery, 1898, describes for *Pentatoma* a structure which arises from one of the chromosomes of the *last* spermatogonial division, and may be plainly seen throughout the spermatocyte divisions. He calls it the "chromatin nucleolus," and there can hardly be a doubt that it corresponds to the accessory chromosome.

McClung, 1899, in the paper in which he proposes the name "accessory chromosome," gives an extended description of the behavior of this

body in *Xiphidium*, beginning with the last division of the spermatogonia and following it through the formation of the spermatozoön. In the spermatocytes, especially in the growth stage, it behaves very much as in *Brachystola*, with the exception that in the divisions of *Xiphidium* it has the form of a curved chromatic body, to both ends of which the spindle fibers attach, while in my object it is a straight or slightly curved rod, receiving the insertion of the fibers at one end only. In the spermatogonia he reports no vesicular stage or other variation from its routine in the spermatocyte.

Paulmier, 1899, describes a similar element for *Anasa* under the name of the "small chromosome." He considers it present in the resting stage of the spermatogonia in the form of two hazy, indefinite masses of chromatin, not breaking down to the same extent as the other chromosomes, and staining with the chromatin stains. In the equatorial plate, these appear as two small chromatic bodies, very much smaller than the other chromosomes, and connected with them by chromatin bands. He says that in the period of spermatocyte growth they reappear as a "*single* body," but fails to describe the manner in which their fusion is accomplished. The behavior of this body in the spireme stage is very similar, indeed, to that of the accessory chromosome in the same stage in *Brachystola*. In the latter, however, it goes into the first spermatocyte division as a longitudinally-split rod, not as a tetrad.

As to the significance of this element, I am hardly prepared to venture an opinion. McClung looks upon it as "possibly representing derivative substances from one or all of the chromosomes." Paulmier offers the suggestion, somewhat along the same line, that it may be an aggregation of ids representing characters at present being lost by the species, basing the supposition chiefly on the fact that, in his material, it goes over bodily, without division, to one of the spermatids in the second spermatocyte division. My observations. it will readily be seen, are hardly corroborative of Paulmier's conclusions. A glance at the figures shows the continuity of the element throughout all the stages, and a carefulness and precision in its movements which are hardly compatible with the supposition that it is a degenerating chromosome. It is obvious that the term "small chromosome" is anything but descriptive of the element in *Brachystola*.

Perhaps the most important thing to be gained at present from the knowledge of the behavior of the accessory chromosome in *Brachystola* is the light which it throws upon the question of the individuality of the chromosomes. In the first place, the fact that it is a true chromosome, though different from the others, is shown by its staining reactions and by the parallelism between its development in the

spermatogonia and that of its more generally recognized fellows. Although it shows a tendency to lag behind the other chromatic bodies, the only radical difference between the two is the absence of the loose spireme in the accessory, and this is paralleled, as shown above, by the normal process of all the chromosomes of *Pyrrhocoris*, according to the statement of Henking. The apparent radical difference in the case of the vesicular stage is, in reality, only a matter of degree, for it frequently happens that the ordinary chromosomes, in going into the diffused condition, leave a very appreciable hollow in their centers (fig. 30). Apparently there is, for some reason, a necessity that the chromatic granules of the accessory come into closer relation with the cyptoplasm than those of its mates, and the result is their deposition upon the vesicle itself — this vesiculation being really a substitute for the loose spireme so conspicuously lacking.

Now, if it be admitted that the body *is* a chromosome, inspection quickly shows us that it maintains throughout the spermatogonial divisions, as well as in those that follow, an indubitable independence, being enclosed, in all stages except those of actual division, in its own individual membrane. Having, then, one of the chromosomes which preserves its individuality in this way, and seeing the other chromosomes enclosed for a part of their development in similar individual vesicles, which only become intercommunicating by absorption of a part of their walls, have we not a right to suppose that at one time they too enjoyed the same independence as their more exclusive mate? In other words, have we not a right to suppose that their phylogeny is paralleled by their ontogeny? If this be granted, then we have at least more ground for belief in the individuality of the chromosomes than if we had never known of a time when they were of necessity independent.

III. *The Sacculated Nucleus.*—In the reconstruction of the nuclear membrane of the secondary spermatogonia of *Brachystola*, we have to do with a condition hitherto undescribed, at least in this sort of cells. This condition is the plurality of nuclear vesicles exhibited at a certain stage of the prophase and retained in a modified form until just before the following metaphase.

The difference from the common type is not one of principle, but rather of time relations. To make this clear, some explanation will be necessary. It is generally admitted that the nuclear membrane of all animal cells is formed between the already differentiated and separate cytoplasm and karyoplasm as a result of certain activities of the chromatin. Polar views of spermatogonia of *Brachystola* in metaphase often show a clearly defined hyaline area around some or all of the chromosomes (fig. 23), and the same condition is sometimes to

be seen in the anaphase, indicating a tendency of the nuclear lymph to accumulate in a zone around each of the chromosomes.

Now, in this case, instead of an aggregation of karyoplasm into a single mass and a general separation of the chromomeres before the formation of the nuclear membrane, the differentiation of the separating layer between cytoplasm and karyoplasm must begin before the chromosomes become attingent at the poles. The result is a separate membrane around each of the little aggregations of nuclear plasm, and consequently around each of the chromosomes.

At this stage, we have a condition in which any interchromosomic exchange of ids is a physical impossibility, and, if we follow the development further, we will be confronted by conditions strongly indicative of the continued maintenance of the individuality of the chromosomes. It is true that soon after the meeting of the chromosomes at the poles dissolution of the contiguous parts of all but one of the vesicles takes place, so that the lymph of one may pass freely to the other; but throughout the whole process of formation of the spiremes, the threads of the different compartments of the nucleus never get in such relations with each other that it would be possible for an id from a given point of one to pass in a straight line to any but a very limited portion of any other. If, therefore, an attraction be postulated between ids of different chromosomes, it would be difficult to see how, by means of the forces now known, or believed, to be present in cell nuclei, an id from the blind end of one of the dilations of the nucleus will ever be able to reach its mutually attracting id in the blind end of another. I may say in connection with this point that the period of complete diffusion, when the interchange might be conceived to be facilitated by currents within the nucleus, is so short that I have been able to find in all my material but a very few cells showing it.

It would be difficult to imagine by what complex laws of attraction a rearrangement of chromomeres or of ids could take place through the tortuous channels of the nucleus which would result in the original number of chromosomes, one and only one lying in each of the compartments of the nucleus.

I would conclude, therefore, that the changes of the nucleus of the secondary spermatogonia are purely metabolic in their nature, and that the individuality of the chromosomes is maintained.

SUMMARY.

1. The testis is unpaired and is composed of short, thick follicles emptying into a common collecting duct, which, in turn, is connected with the *vas deferens.* Inside the follicles of the adult testis, the spermatozoa may be found in large numbers at the end nearest the

collecting duct; next comes the zone of the spermatids, then the spermatocytes, and then, when they are present at all, the secondary and primary spermatogonia.

2. Older cysts are always nearer the *vas deferens* than those of later development, except in the zone of the spermatogonia, the center of which is occupied by primary spermatogonia, while the cysts of secondary spermatogonia are arranged irregularly between the latter and the follicular wall.

3. Primary spermatogonia divide by mitosis. They may be distinguished from the secondary variety by their smooth, oval, vesicular nuclei, and their relatively small amount of chromatin, as well as by the fact that they are disposed irregularly and not in cysts, as are the older generations. Most of the primary spermatogonia ultimately produce spermatozoa, but a few remain in the resting stage and, moving with the mature cysts toward the *vas deferens*, supply these membranes with nourishment.

4. In preparation for the last division, the flakes of chromatin of the resting primary spermatogonial nucleus become diffused and a number of spiremes are formed. These become shorter, split longitudinally, and then assume the form of short split or double rods — apparently all alike. There is no nucleolus. The nuclear membrane now dissolves, the chromosomes arrange themselves in the equatorial plate, and the spindle, with its two tiny, deeply-staining centrosomes, may be clearly seen. The chromosomes next divide along the line marked out in the prophase, and the halves are drawn to their respective poles, thus producing two secondary spermatogonia. Around these two cells a membrane appears, forming a two-cell spermatocyst.

5. Each chromosome, on reaching the pole, begins to disintegrate, and, at the same time, reconstructs its share of the nuclear membrane as a closed vesicle about itself. Later, all the vesicles become intercommunicating at their polar extremities, with the exception of one, which remains absolutely independent throughout its entire existence. The chromatin of the ordinary chromosomes becomes diffused evenly in the nuclear space, while that of the one in the separate vesicle (the accessory chromosome) is deposited upon the inner surface of its capsule.

6. Following this, the chromatin of the joined vesicles goes through the fine and coarse spireme stages, forming in each of the sacculations of the nucleus a thick, spiral segment which splits longitudinally, and afterward becomes a chromosome like that of the primary spermatogonia. The accessory chromosome has no spireme stage, but merely collects in the form of a straight or twisted rod, which splits after the manner of the others. All the chromosomes line up in the same man-

ner in the equatorial plate, and in many cases the accessory chromatin element cannot be distinguished from its fellows.

7. Slightly before the occurrence of the longitudinal split of the chromosomes, the centrosomes, connected by a minute centrodesmus, appear in the portion of the cell containing the greatest mass of cytoplasm, and slowly move apart until they become diametrically opposite each other. About this time, first the nuclear membrane, then that of the accessory chromosome, is dissolved.

8. The metaphase, anaphases and telophases occur precisely as in the previous division. These processes are repeated until each cyst contains secondary spermatogonia of the seventh or eighth generation, when the transformation to spermatocytes occurs.

9. In the telophases of the last spermatogonial division the sacculations of the nucleus entirely disappear, leaving a smooth, vesicular membrane, to which the vesicle of the accessory chromosome is very closely applied.

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EXPLANATION OF PLATES XXXII, XXXIII, XXXIV, XXXV.

All drawings are from camera lucida outlines. For all except fig. 1, a B. & L. $\frac{1}{12}$-inch oil immersion objective and a 1-inch B. & L. ocular were used. The length of the tube for all drawings was 160 mm., and the drawing-board was at the height of the stage. For fig. 1, a B. & L. $\frac{1}{6}$-inch objective was used, the other conditions being those named above. In reproduction, the drawings are reduced one-fourth, giving a final magnification of 375 diameters for fig. 1, and 900 for the others.

Figs. 2 to 38, inclusive, are numbered as nearly as possible in the order of their development, with the exception that fig. 39 properly belongs between figs. 19 and 20.

The photomicrographs were made with a Zeiss 2-mm. apochromat objective and a Zeiss projection eyepiece. The source of illumination was the crater of the electric arc.

Figs. G and D have an actual magnification of 728 diameters, and the remaining figures 1120 diameters, being reduced one-fifth in reproduction, from 910 and 1400, respectively.

Drawings and photomicrographs are by the author, the latter especially, with valuable assistance from Professor McClung.

DRAWINGS.

FIG. 1. Longisection of blind end of follicle, showing all of spermatogonia and one cyst (*Spc*) of spermatocytes. The cyst membranes may be plainly seen around their respective spermatocysts; and between the latter, the primary spermatogonia with their large, vesicular nuclei. Many of the secondary spermatogonia show the vesicular condition of the accessory chromosome, while the prominent black objects on peripheries of the spermatocyte nuclei represent a later stage of the same. At *n*, *n*, may be seen the nuclei of the follicular wall.

FIG. 2. Resting stage of primary spermatogonium, chromatin arranged in patches connected by linin threads. Quantity of cytoplasm is unusually large.

FIG. 3. Early stage of development of primary spermatogonium — chromatin becoming more diffused.

FIG. 4. Slightly later stage. Chromatin almost ready for the formation of the spireme.

FIG. 5. Early prophase. A number of spiremes enclosed in a single nuclear membrane.

FIG. 6. Later prophase. Spiremes short and thick and connected by linin fibers.

FIG. 7. Fragment of cell (shown also in fig. D), having chromatin threads split longitudinally.

FIG. 8. Late prophase—just before division.

FIGS. 9 and 10. Oblique sections of primary spermatogonia in metaphase.

FIG. 11. Telophase of primary spermatogonium.

FIG. 12. Cross-section of "fingers" of nucleus of later telophase.

FIG. 13. Cell at dividing line between metaphase of one cycle and prophase of the next. Accessory chromosome shown as small dense body on the right. As in fig. 12, the section is through the "fingers" of the nueleus.

FIG. 14. Lateral view of early prophase of secondary spermatogonium, showing characteristic form and arrangement of young spiremes.

FIG. 15. Fragment of secondary spermatogonium in later prophase, showing the "hand of the glove" containing the ends of all the spiremes. The irregular body at the right is a portion of the accessory chromosome—the rest being cut away. At A is a complete accessory chromosome with its membrane, drawn from another cell of the same cyst. Below may be seen a persisting spindle between two neighboring cells.

FIG. 16. Longisection of "fingers" of nucleus, showing partition walls partly dissolved. Accessory chromosome twisted like a rope.

FIG. 17. Cell at a stage similar to above. Nucleus showing irregular dissolution of partition, forming a number of larger vesicles.

FIG. 18. Cross-section of "hand" of nucleus, showing ends of spiremes.

FIG. 19. Longisection of sacculations of nucleus.

FIG. 20. Late prophase. Nuclear membrane dissolved. Chromosomes of a homogeneous structure. Centrosome and aster in lower right-hand corner.

FIG. 21. Prophase just before division. Chromosomes moving toward equatorial plate. Nuclear membrane dissolved. Accessory chromosome still enclosed in its membrane and granular in structure, while the others are homogeneous. At *a* is drawn an accessory chromosome with its membrane from another cell of the same cyst. It is split longitudinally and twisted like a two-strand rope.

FIG. 22. Metaphase of secondary spermatogonium. Accessory chromosome indistinguishable from its mates.

FIG. 23. Polar view of metaphase. Chromosomes divided and ready to be drawn apart. Clear areas filled with karyoplasm may be seen around the different chromosomes.

FIG. 24. Anaphase. Accessory chromosome distinguishable by its greater length and rougher contour.

FIG. 25. Anaphase, showing elliptical course traversed by the chromosomes in their course toward the poles.

FIG. 26. Early telophase, showing connecting fibers forming a cylinder.

FIG. 27. Later telophase. Masses of chromosomes have moved much farther apart than were the centrosomes in the metaphase. Connecting fibers form a hyperboloid, and each has developed on it at the point where it pierces the partition wall a small but deeply staining enlargement.

FIG. 28. Cross-section of spindle, showing nearly all the fibers arranged in an outer cylinder, a very few being irregularly disposed within.

FIG. 29. Telophases, showing sixteen chromosomes in each daughter-cell.

FIG. 30. Later telophase. Membranes formed and already fused, producing a single sacculated or glove-shaped nucleus. Apparent longitudinal split of chromosomes due to the fact that they are hollow.

FIG. 31. Two daughter-cells, showing incomplete separation in halves of the accessory chromosome. The partition wall has constricted across and is cutting off one of the accessory chromosomes which has already entered upon the vesicular stage. A thickening of the free margin of the partition wall may be seen where it presses upon the connecting element. The cells have rolled upon one another so that they are now side by side instead of end to end.

FIG. 32. Slightly later telophase, showing chromosomes and membranes in cross-section. Some of the sacculations of the nucleus appear to have fused throughout their length.

FIG. 33. Telophase of last generation of secondary spermatogonium, showing vesicular chromosome on right and almost complete loss of partitions between the pockets of the nuclear cavity.

FIG. 34. Cell in similar stage, showing vesicular chromosome in cross-section. The apparent longitudinal split of chromosomes is due to the hollow space in the middle of each. Cross-hatched body below nucleus is to represent spindle remains, which in this case had become homogeneous and apparently stained only with the osmic acid.

FIG. 35. Fragment of cell, showing entire vesicular chromosome.

FIG. 36. Late telophase of last generation of spermatogonia. Accessory chromosome is of about the same density as the others, and is closely applied to the nuclear membrane. Spaces between pockets of nucleus are reduced to mere furrows in the nuclear wall. Chromosomes have begun to lose their former sharp outlines.

FIG. 37. Later stage. Accessory chromosome has become more condensed. Nuclear membrane is smoother and the outlines of the chromosomes are entirely lost.

FIG. 38. Early spermatocyte, spireme forming. Both nucleus and cell body have increased greatly in size. Accessory chromosome, closely invested by its membrane, lies partly imbedded in the nuclear wall. The former is divided in the section and in its center may be seen the persisting cavity of the vesicular stage. Cross-hatched bodies above the accessory chromosome are spindle remains, similar to those described for fig. 34.

FIG. 39. This figure represents a stage of development between figs. 19 and 20. The condition of the chromosomes as almost straight double rods is unusual. At the side of the cell opposite to that occupied by the centrosome in the previous division may be seen the centrosomes of the next, each with its aster, and the two separated by a minute centrodesmus. The accessory chromosome does not appear.

FIG. 40. Degenerating primary spermatogonium, from center of young cyst.

FIG. 41. Section through upper portion of resting primary spermatogonium which has assumed the function of a cyst cell.

PHOTOMICROGRAPHS.

FIG. A. View of a portion of follicle near its edge. Just above the lower fourth of the picture may be seen the follicular wall. In the lower fourth is the connective-tissue investment of the testis. The large cell in the center is a secondary spermatogonium in prophase. At *x* is the accessory chromosome, twisted like a corkscrew, and enclosed in its own membrane. To the left is a very early prophase; below and at the upper right hand are later ones: and below and above, to the left, are prophases of primary spermatogonia. The cyst walls are not in focus.

FIG. B. Above are secondary spermatogonia in metaphase and anaphase; zones of clear karyoplasm may be seen around most of the chromosomes. Below and to the right are secondary spermatogonia in telophase, showing the sacculated nucleus. To the left of these are two primary spermatogonia in resting stage.

FIG. E. Metaphase of secondary spermatogonium.

FIG. G. Young cyst of secondary spermatogonia with degenerating primary spermatogonium in the center. Cells of upper half are in anaphase; those of lower half, in middle or late telophase: *s* marks a chain of spindle remains extending through three cells. On the left is the follicular wall, within which is the cyst membrane—the latter being plainly visible entirely around the cyst.

FIG. H. Primary and secondary spermatogonia. Above is the cell shown in fig. 18. Below and to the left is a secondary spermatogonium in late prophase. To the right is a primary spermatogonium in prophase, and, below this, another in metaphase.

FIG. C. Mass of primary spermatogonia. Cell in the center is in late prophase.

FIG. D. Primary and secondary spermatogonia. At the upper right hand is a cyst of secondary spermatogonia, while a corner of a similar one may be seen just below. The remaining cells are primary spermatogonia. To the left of the center may be seen the cell from which fig. 7 was drawn. In the lower right-hand corner is a resting stage, and, to the left of this, the metaphase of which fig. 10 is a drawing. At *a* is an open space formed by the separation of the cell-wall from its enveloping capsule, forming the earliest manifestation of the future cyst membrane.

FIG. F. Telophases of secondary spermatogonia. At *x* is the vesicular chromosome.

FIG. I. Diaster of secondary spermatogonia. Below, an early anaphase. In the lower left-hand corner, a primary spermatogonium in prophase.

FIG. J. Telophases of secondary spermatogonia. At *x*, *x*, are vesicular chromosomes. At *s*, a persisting spindle, with thickenings upon the fibers where they pierce the cell-walls. The spindle passes through the edge and not the center of the partition wall.

ANNOTATED LIST OF THE MINERALS OCCURRING IN THE JOPLIN LEAD AND ZINC DISTRICT.

BY AUSTIN F. ROGERS.*

THE minerals of the lead and zinc district of southeastern Kansas and southwestern Missouri, commonly called by the name of its metropolis, the Joplin district, have received but comparatively little attention. The following list, which is thought to be practically complete, includes all the minerals that have been reported from the district, together with some here mentioned for the first time. The minerals, with a few exceptions, have been personally collected by the writer. Different lists of the minerals of the region have been published in geological survey reports and elsewhere, the largest of which has but twenty-one names, whereas the list here given includes forty-three.

The minerals are arranged alphabetically. Those new for the district are indicated by †. A fuller discussion of the latter follows the list proper. Minerals indicated by ‡ have been found in or about Galena, and are therefore new for Kansas, having never been reported from the state.

1. *Allophane.*†‡

2. *Aluminite*, as a white incrustration on limestone at Joplin. Reported by Prof. H. A. Wheeler.

3. *Anglesite.*

4. *Aurichalcite.*‡ Pale bluish-green tufts with velvety surface, associated with malachite. Found at Granby, Mo., and Galena, Kan.

5. *Azurite.* A very rare mineral in the district.

6. *Barite.*

7. *Bitumen.* Plentiful at Joplin and Webb City; very rare at Galena.

8. *Calamine.* Some crystals from Granby exhibit both the analogous and antilogous ends, commonly as botryoidal and stalactitic incrustations; also pseudomorphous after calcite and dolomite, especially at Granby.

9. *Calcite.* Very interesting from a crystallographic standpoint.

10. *Caledonite.*†‡

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*Published by permission of the director of the University Geological Survey of Kansas in advance of final report on lead and zinc.

11. *Cerussite.* Six-rayed stellate twins are not uncommon; occurs as a pseudomorph after galena.

12. *Chalcopyrite.* Rather common, but never in large quantities. Almost invariably exists as crystals of the tetragonal sphenoid, with a tetrahedrid aspect.

13. *Chrysocolla.*†‡

14. *Copiapite.*†‡

15. *Covellite.*†‡

16. *Cuprite.*†‡

17. *Dolomite.* As white or pink rhombohedral crystals with the characteristic curved faces. Very common at Joplin; much less so at Galena.

18. *Galena.* Lamellar twinning is very common in the galena of the district. The twinning planes are several vicinal trigonal trisoctahedra with high indices, near the rhombic dodecahedron in position.

19. *Goslarite.* Occurs as a white fibrous product resulting from the oxidation of the white amorphous zinc sulfid, found on the Moll tract at Galena.

var. *Ferrogoslarite.* Described by H. A. Wheeler, from Webb City, as a brown stalactitic incrustation in abandoned zinc mines. Contains 4.9 per cent. $FeSO_4$.

var. *Cuprogoslarite.* Described by the writer* from Galena, where it occurs as a light greenish-blue incrustation, associated with sphalerite and chalcopyrite, by the oxidation of which it was doubtless produced. Contains 12.48 per cent. $CuSO_4$.

20. *Greenockite.* A greenish-yellow coating on sphalerite. Very rare.

21. *Gypsum.*†

22. *Hematite.*†

23. *Hydrozincite.* A white amorphus incrustation, associated with calamine and smithsonite, often as a thin layer between the two. Found at Granby,

24. *Kaolinite.*†

25. *Leadhillite.* Fully described by Pirsson and Wells** as pale green monoclinic crystals with hexagonal aspect, from the "Beer Cellar" mine at Granby. Also pseudomorphous after calcite and galena.

26. *Limonite.* This mineral occurs pseudomorphous after pyrite, marcasite, and chalcopyrite.

27. *Linarite.*†‡

28. *Malachite.* Rather common throughout the district.

*This journal, vol. VIII, pp. 105, 106, 1899.

**Amer. Journ. Sci., vol. XLVIII (3), p. 219, 1894.

29. *Marcasite.* Twins are abundant, among them cyclic fivelings.

30. *Melanterite.* White crystalline powder produced by the oxidation of pyrite or marcasite.

31. *Mimetite.* Reported by Dr. W. P. Jenney as a thin crystalline coating on galena, at Seneca, Newton county, Missouri.

32. *Muscovite.*†

33. *Opal,* var. *Tripoli,* as extensive beds of soft, massive, white to buff-colored material.

34. *Pyrite.* Quite common, but not as abundant as marcasite.

35. *Pyrolusite.*†

36. *Pyromorphite.*‡ Small grass-green prismatic crystals and coating on chert. Found at Granby, Joplin, and Galena. At Granby it is pseudomorphous after galena.

37. *Quartz.* The crystals are usually very small, but some from Granby and Wentworth measure two and one-half cms. in the direction of the vertical axis.

38. *Smithsonite.* In small crystals, with rounded faces, but more often as stalactitic and botryoidal forms; also pseudomorphous after calcite and dolomite, especially at Granby.

39. *Sphalerite.* A white amorphous of zinc sulfid was described by Robertson,* from Galena and near Joplin.

40. *Sulfur.*†

—. *Tripoli.* See Opal.

41. *Vivianite.* Reported by Dr. G. Hambach as blue, earthy powder from Joplin.

42. *Wavellite.* Reported by Dr. G. C. Broadhead as small, white, radiating crystals on chert from Jasper county.

43. *Wurtzite.* Small hexagonal crystals on stalactitic sphalerite, at Joplin. By whom first found is not known by the writer.

44. *Chalcanthite.* The writer has recently found this mineral at the Irene Mining Company's mine, in Empire City, Cherokee county, Kansas. It occurs as small blue columnar crystals, associated with sphalerite, pyrite, and chalcopyrite, and is doubtless the result of the oxidation of the latter. The specimens were found on the dump piles, but the miners say that the mineral is frequently observed on material just after it is hoisted from the shaft.

Allophane? A hydrous aluminium silicate related to allophane in composition occurs at the "Big Coon" mine and at the mine of the Dearborn Mining Company, at Galena, Kan. The mineral appears as a thin incrustation, often with a botryoidal surface, associated with sphalerite, chert, and a soft, clay-like material. It is amorphous, colorless to light brown or green, subtranslucent to translucent, with res-

*Amer. Journ. Soc., vol. XL (3), pp. 160, 161, 1890.

inous luster, and has very much the appearance of gum arabic. In physical characters agrees very well with the description of schoetterite, but is quite different in chemical composition. Mr. C. A. Wolfaith, superintendent of the Dearborn mine, kindly furnished the material for analysis. An analysis gave the following, which is the mean of two determinations: Al_2O_3, (41.66); SiO_2, 24.76; H_2O, 33.58; total, 100.00. Specific gravity = 1.94. The silica percentage is rather high and the water percentage rather low for allophane, but it is much nearer that mineral than any other, and so is referred to it with a query.

Caledonite. Occurs in very small quantities as a green crystalline coating, associated with linarite, aurichalcite, and cerussite (with a little unaltered galena), at the "Big Coon" mine, Galena. Heated in the closed tube, becomes black and gives off water. Reacts for Pb, Cu, and SO_4. Soluble in nitric acid, leaving a white residue of lead sulfate. Has been reported from but two or three localities in the United States.

Chrysocolla. This mineral occurs as thin seams of the characteristic bluish-green color associated with other copper minerals at the "Big Coon" mine, Galena.

Copiapite. A basic ferric sulfate, referred to copiapite, occurs as a yellow crystalline incrustation on pyrite at Galena and at Cave Springs, Mo., being especially abundant at the "Pilgrim" mine at the latter locality, where it occurs on the walls of a cave-in.

Covellite. The sphalerite from the "Big Coon" mine is often coated with a bluish-black substance, which is seen to penetrate the cleavage faces for a considerable distance. This mineral it is thought is covellite, as it agrees with it in physical characters and, as far as can be determined, in chemical composition. It seems probable that a metathetic reaction has taken place between zinc sulfid and copper sulfate, thus: $ZnS + CuSO_4 = CuS + ZnSO_4$. Such a reaction does take place when sphalerite is heated in a closed tube containing a solution of copper sulfate at a temperature of 200 degrees, as experiments by the author show. Given sufficient time and favorable conditions, may not this reaction have taken place without the high temperature? Exterior to the covellite is often malachite, which is a further product of the decomposition of the covellite. Here, then, we have covellite and malachite pseudomorphous after sphalerite.

Cuprite. Cuprite was observed as a central core surrounded by malachite, from which the latter was evidently formed. The cuprite, it is believed, is also secondary, and probably has been formed from chalcopyrite, which seems to be the only original copper mineral of the region. This opinion is largely suppositious, as there is no evi-

dence that the cuprite has been derived from any preexisting mineral, as far as the examination of the specimens shows.

Gypsum. Crystals of this mineral are found in bituminous shale, probably of Coal Measure age, on the Mastin ground, southwest of Galena; also of recent origin, coating the chert in old dump piles.

Hematite. Occurs as a thin, black, botryoidal incrustation and soft red stain on chert in Cooper Hollow, Galena.

Kaolinite. Found as a thin white coating on micaceous shale at Cave Springs, Mo.; also as powder in cavities in chert at the "Tree Toad" mine.

Linarite. A mineral answering the tests of linarite was found in very small quantities at Galena. It is azure-blue in color, with vitreous luster, and reacts for lead, copper, and sulfuric acid; gives off water and loses its color when heated in closed tube; soluble in nitric acid, leaving a white residue of lead sulfate. It is associated with cerussite and malachite as a thin layer between them. Linarite seems to have been reported from but two other localities in this country — at the Cerro Gordo mines, Inyo county, California, and Organ mountains, near Las Cruces, N. M.

Muscovite. Occurs as crystalline scales in shale at the Cave Springs mines and is no doubt of secondary origin.

Pyrolusite. A soft, black mineral from a shaft west of "Black Hill," in the western part of Galena, is probably pyrolusite. It has a botryoidal surface; the streak is black with submetallic luster. Reacts for manganese and in the closed tube gives off a small amount of water, as pyrolusite often does. Dendritic markings on the chert at Granby may probably be referred to this mineral.

Sulfur. This mineral was found as minute crystals and as a thin crystalline coating on cleavage surfaces of galena. Galena in decomposing ordinarily gives rise to the carbonate, cerussite, passing perhaps through the intermediate stage of the sulfate, the sulfur being oxidized. The sulfur in the occurrence here described was not oxidized, but set free, remaining as the native element. Sulfur was also observed in cavities in sphalerite, as before in very small quantities. Both the galena and sphalerite thus associated are from the "Bonanza" ground, northwest of Galena. As far as can be learned, this is the first notice of native sulfur derived from sphalerite.

MINERALOGICAL LABORATORY, UNIVERSITY OF KANSAS, MAY 1, 1900.





PLATE XVIII.

Fig. 1.—*Chionaspis ortholobis* Comstock, on *Salix* sp. Anal plate of female, showing somewhat irregular position of dorsal glands.

Fig. 2.—*Chionaspis ortholobis* Comstock, on cottonwood, *Populus* sp. Anal plate of female, illustrating variations in second and third lobes. The dorsal glands, second and third rows, in this figure, as in figure 1, are shown beneath the circumgenital glands. These are frequently located laterad of circumgenital glands.

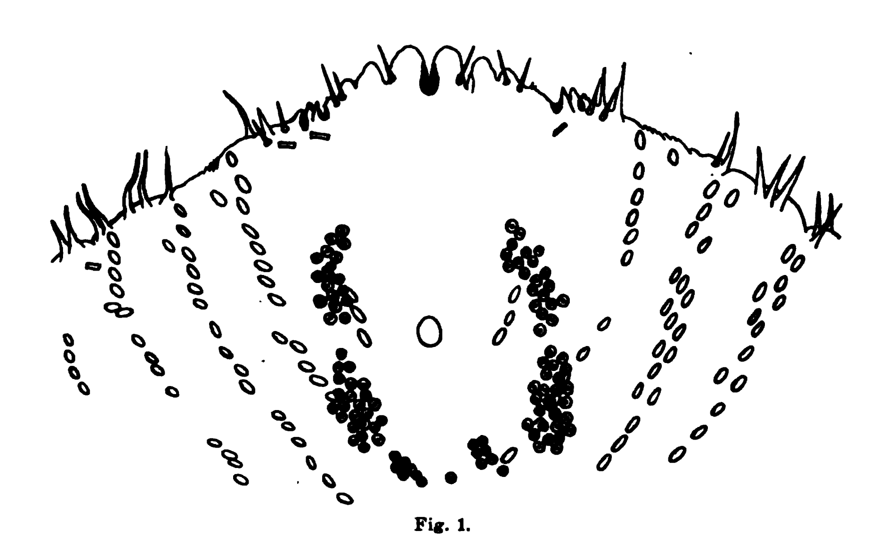
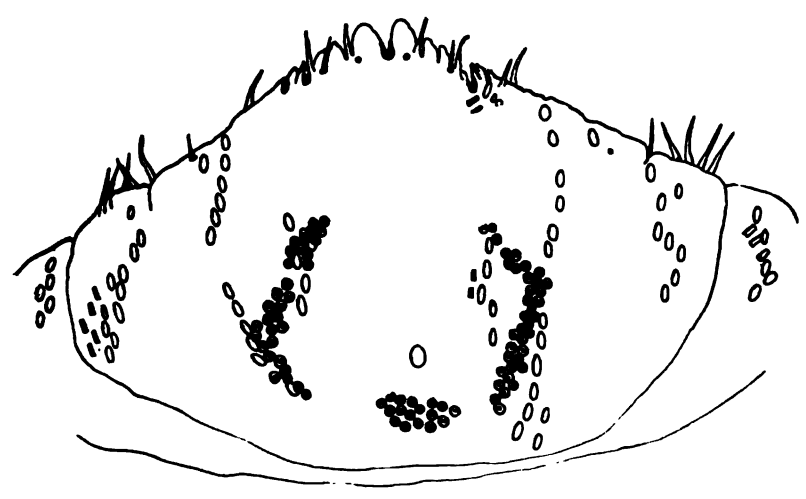


Fig. 1.



Ella Weeks, del. ad nat.

Fig. 2.



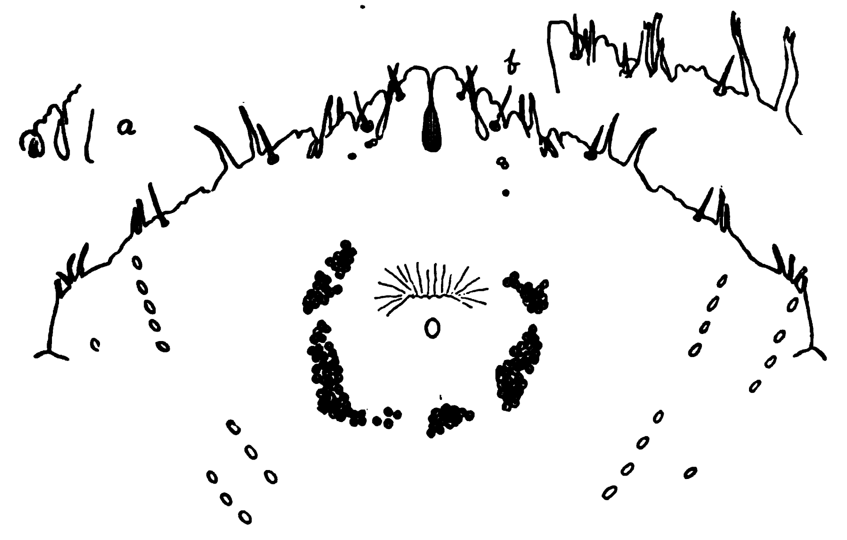
PLATE XIX.

Fig. 1.—*Chionaspis salicis-nigræ* Walsh, on *Salix* sp. Anal plate of female.

Fig. 2.—*Chionaspis americana* Johnson, on *Ulmus americana*. Anal plate of female. (*a*) Variation in margin of median and second lobe; (*b*) illustrates marginal variations and forked plates.



Fig. 1.



Ella Weeks, del. ad nat.

Fig. 2.

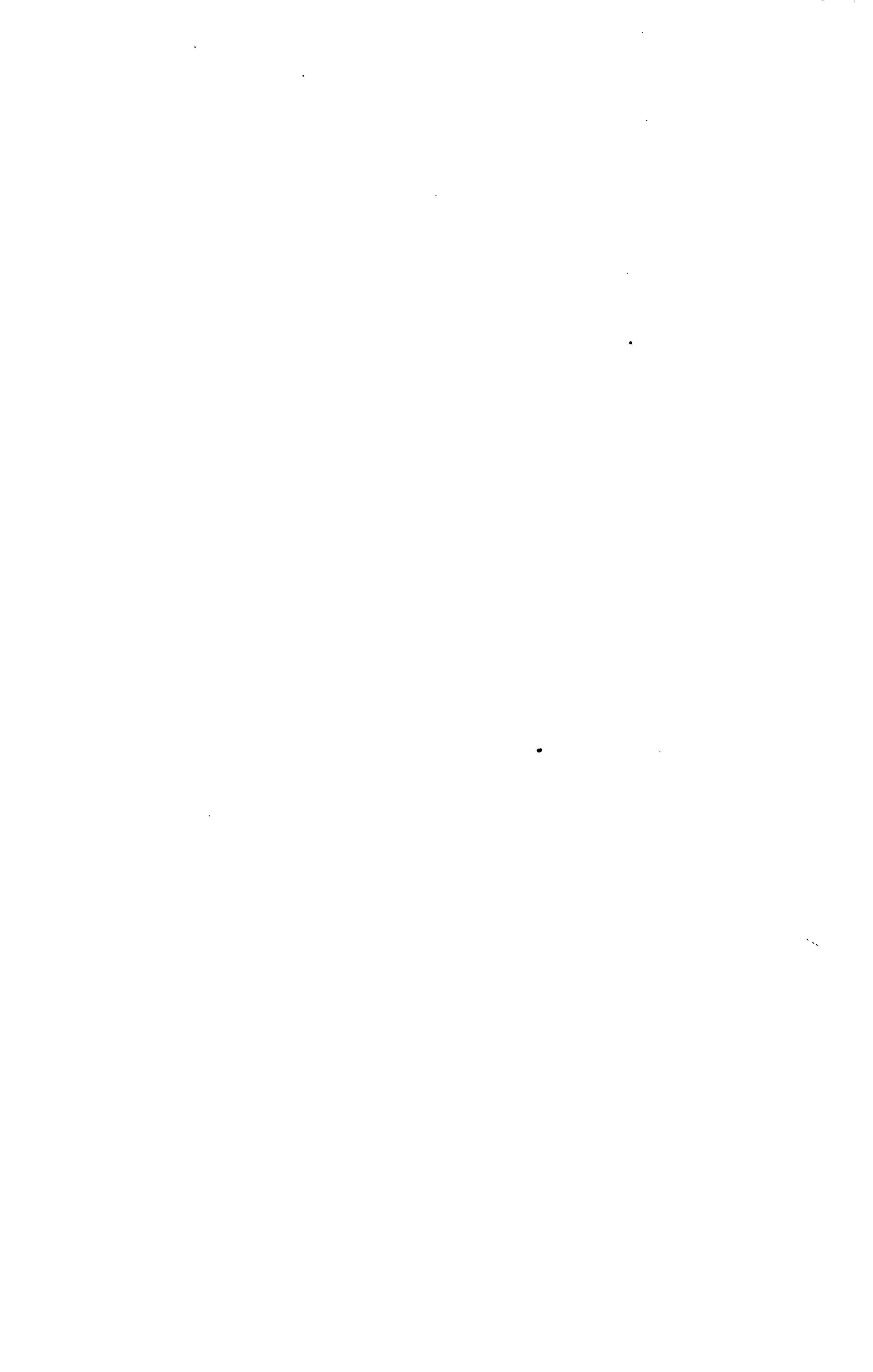


PLATE XX.

Fig. 1.—*Chionaspis platani* Cooley, on sycamore, *Platanus occidentalis*. Anal plate of female.

Fig. 2.—*Chionaspis pinifoliæ* Fitch, on *Pinus* sp. Anal plate of female.

PLATE XX.

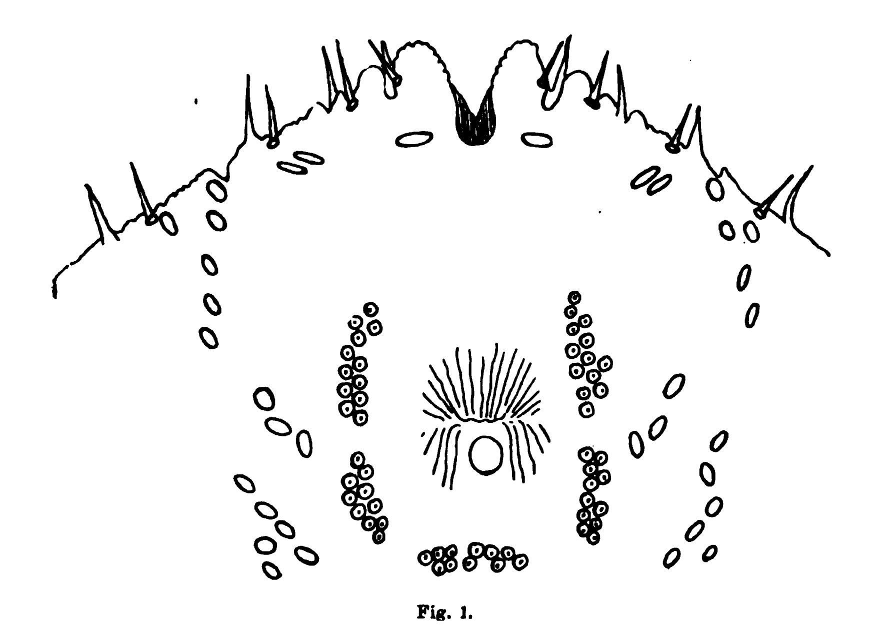


Fig. 1.

Ella Weeks, del. ad nat.

Fig. 2.



PLATE XXI.

Fig. 1.—*Pulvinaria innumerabilis* Rathv. Leg and antenna of female. Greatly enlarged.

Fig. 2.—*Pulvinaria innumerabilis* Rathv. Adult female on twig, the cottony covering of the egg mass frayed by the weather. Enlarged.

Fig. 3.—*Pulvinaria pruni*, n. sp. Sketch of nymph, its antenna, and leg, at time of location upon the plum leaf. Enlarged.

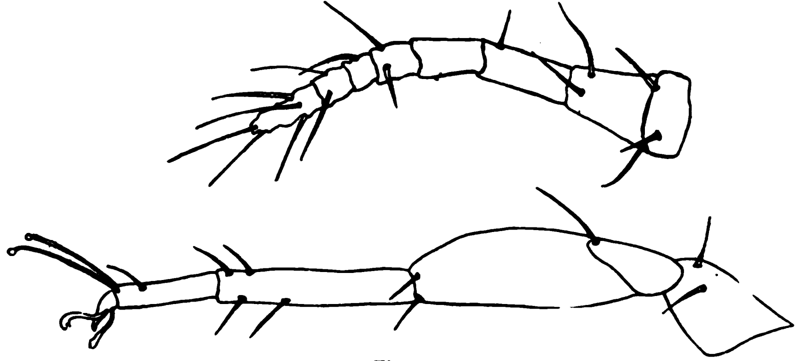


Fig. 1.

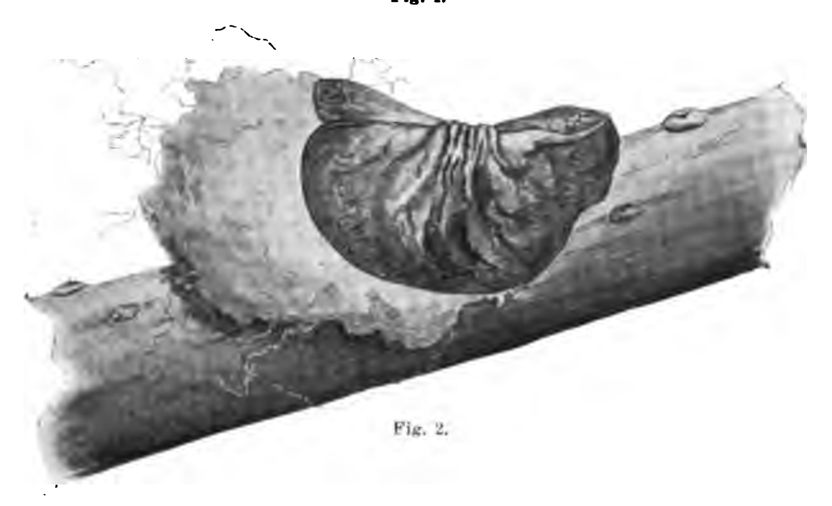


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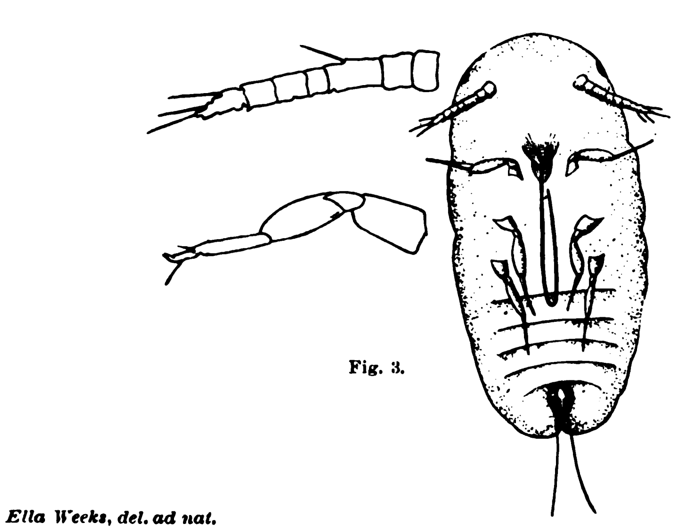


Fig. 3.

Ella Weeks, del. ad nat.



PLATE XXII.

Pulvinaria pruni, n. sp., on leaves and twig of plum. Adult females, being much recurved and shriveled, do not show clearly at the ends of the cottony egg masses.



From a photograph.





PLATE XXIII.

Fig. 1.—*Pulvinaria pruni*, n. sp. Antenna. Anterior (*A*), median (*B*), posterior (*C*) legs of adult female on leaves of plum. Greatly enlarged.

Fig. 2.—Antenna. Anterior (*A*), median (*B*), posterior (*C*) legs of adult female on plum twigs. Greatly enlarged.

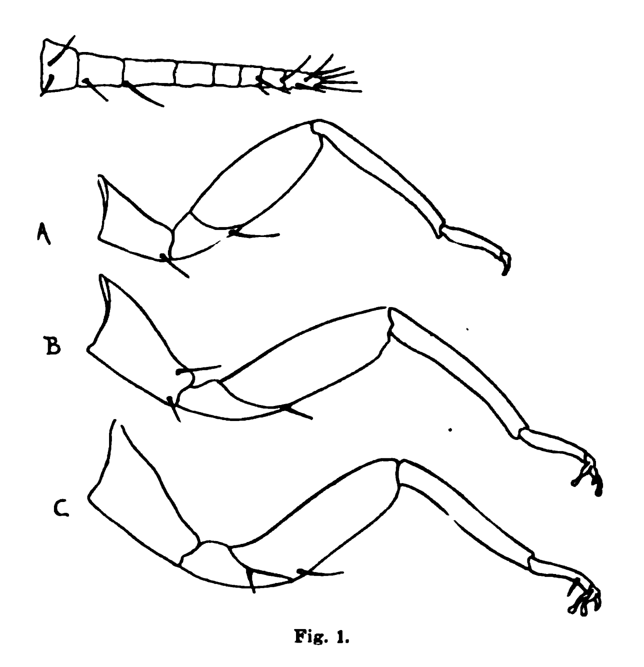
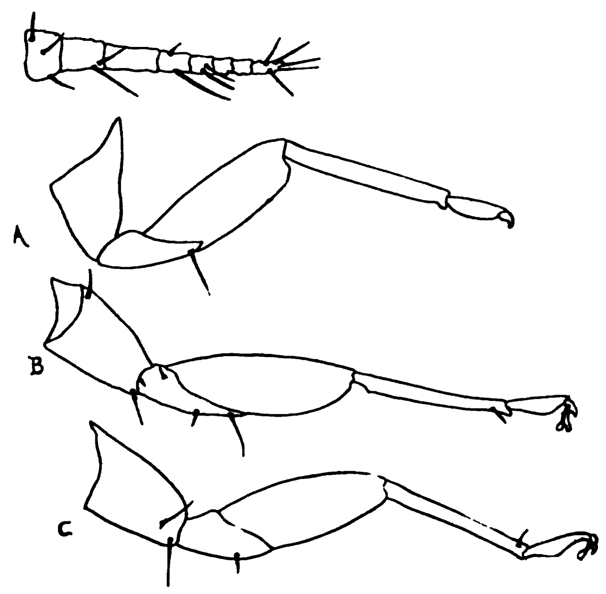


Fig. 1.



Ella Weeks, del. ad nat.

Fig. 2.





PLATE XXIV.

Fig. 1.—*Parlatoria pergandei* Comstock, on orange, *Citrus* sp.

Fig. 2.—(*a*) *Parlatoria pergandei.* First, second, third and fourth lobes, with variations. (*b*) *Parlatoria proteus* Curt., on *Pinus insignis.*

Note the variation in the papillar fourth lobe of *pergandei*, and presence of plate beyond fourth lobe of *proteus.*

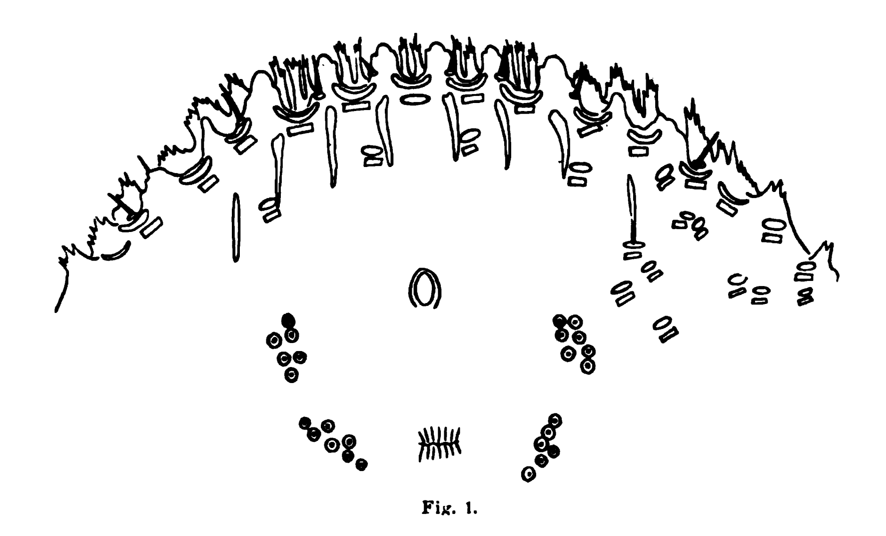
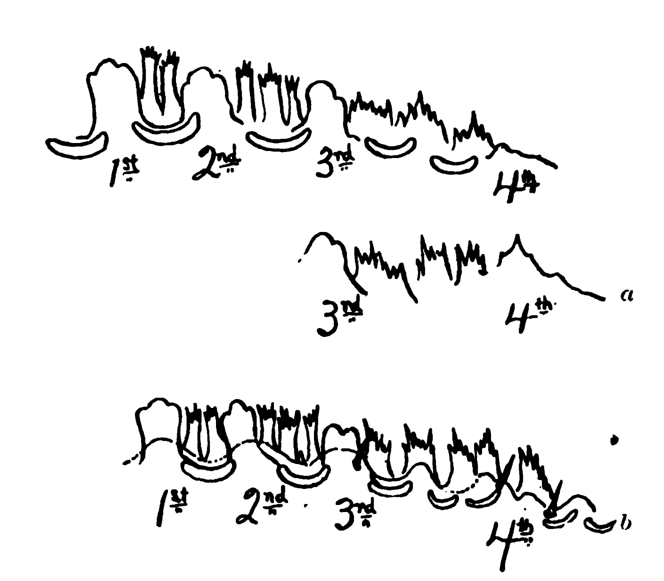


Fig. 1.



Ella Weeks, del. ad nat.

Fig. 2.



PLATE XXV.

Belemnites densus Meek and Hayden.

Fig. 1.—View of three young individuals.

Vermes.

Fig. 2.—Sandstone containing worm borings.

Pentacrinus astericus Meek.

Fig. 4.—Stem enlarged (after Clark).

Fig. 5.—Articulating surface (after Clark).

Fig. 6.—Stem with cirri (after Clark).

Fig. 7.—View of cirrus (after Clark).

Asterias dubium Meek.

Fig. 4.—View of upper surface.

Cardinia wyomingensis, n. sp.

Fig. 8.—Exterior view of valve.

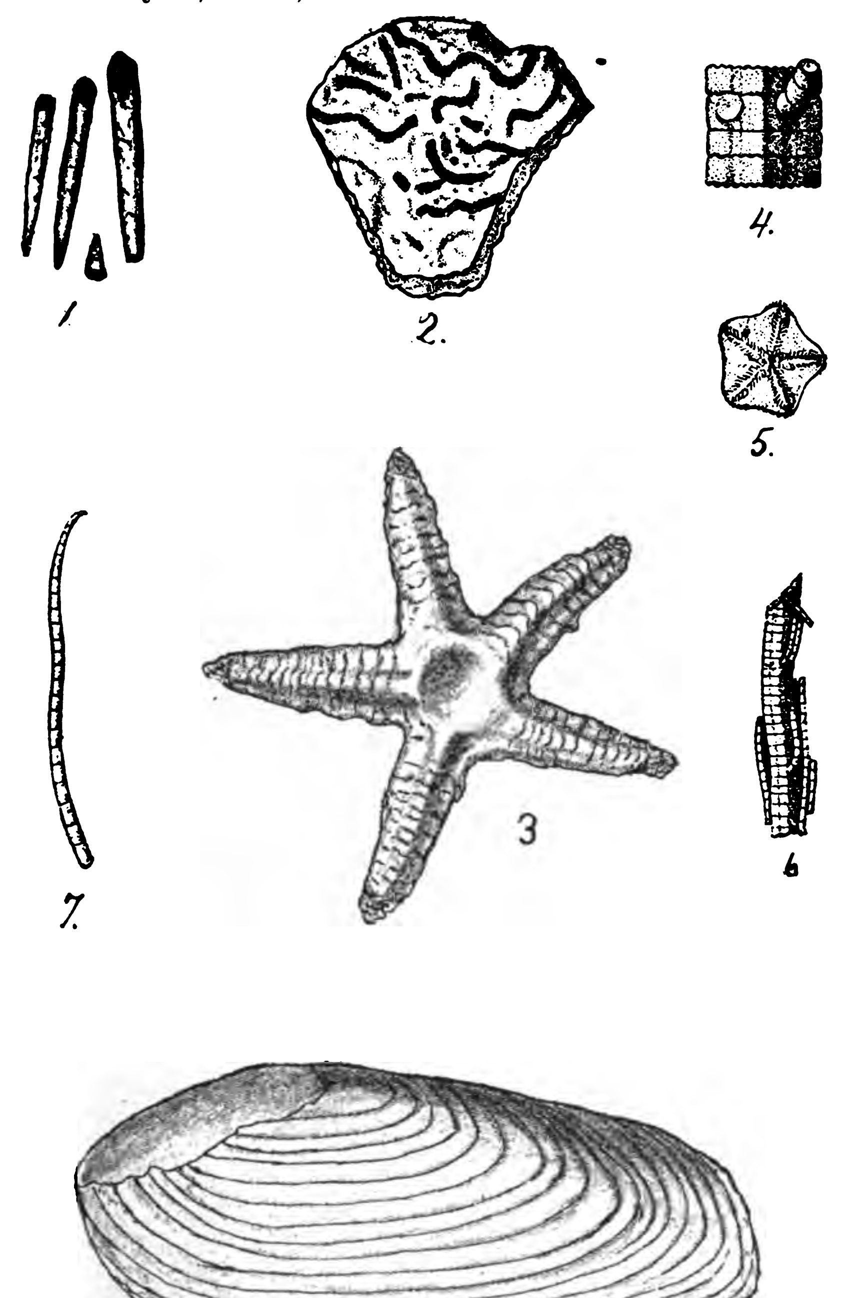

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PLATE XXVI.

Goniomya montanaensis Meek.
Fig. 1.—Exterior view of valve.

Goniomya, sp.
Fig. 2.—View of incomplete specimen.

Belemnites curtus, n. sp.
Fig. 3.—Specimen split to show the structure.

Pleuromya subcompressa Meek.
Figs. 4, 7, 8.—Three views of shell.

Pholadomya robusta, n. sp.
Figs. 5, 6.—Views of two individuals.

Belemnites densus Meek and Hayden.
Fig. 9.—View of average-size specimen.

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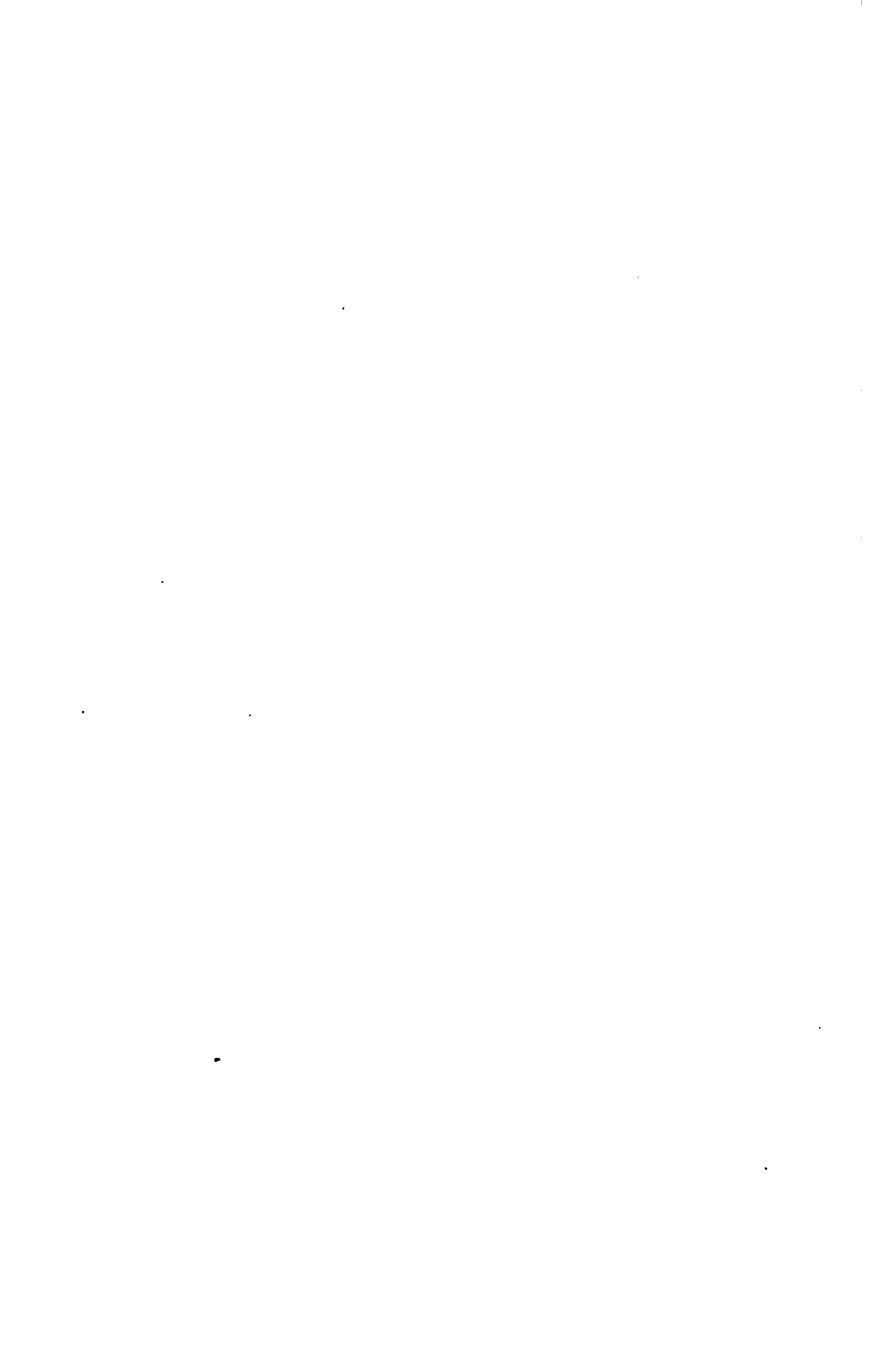
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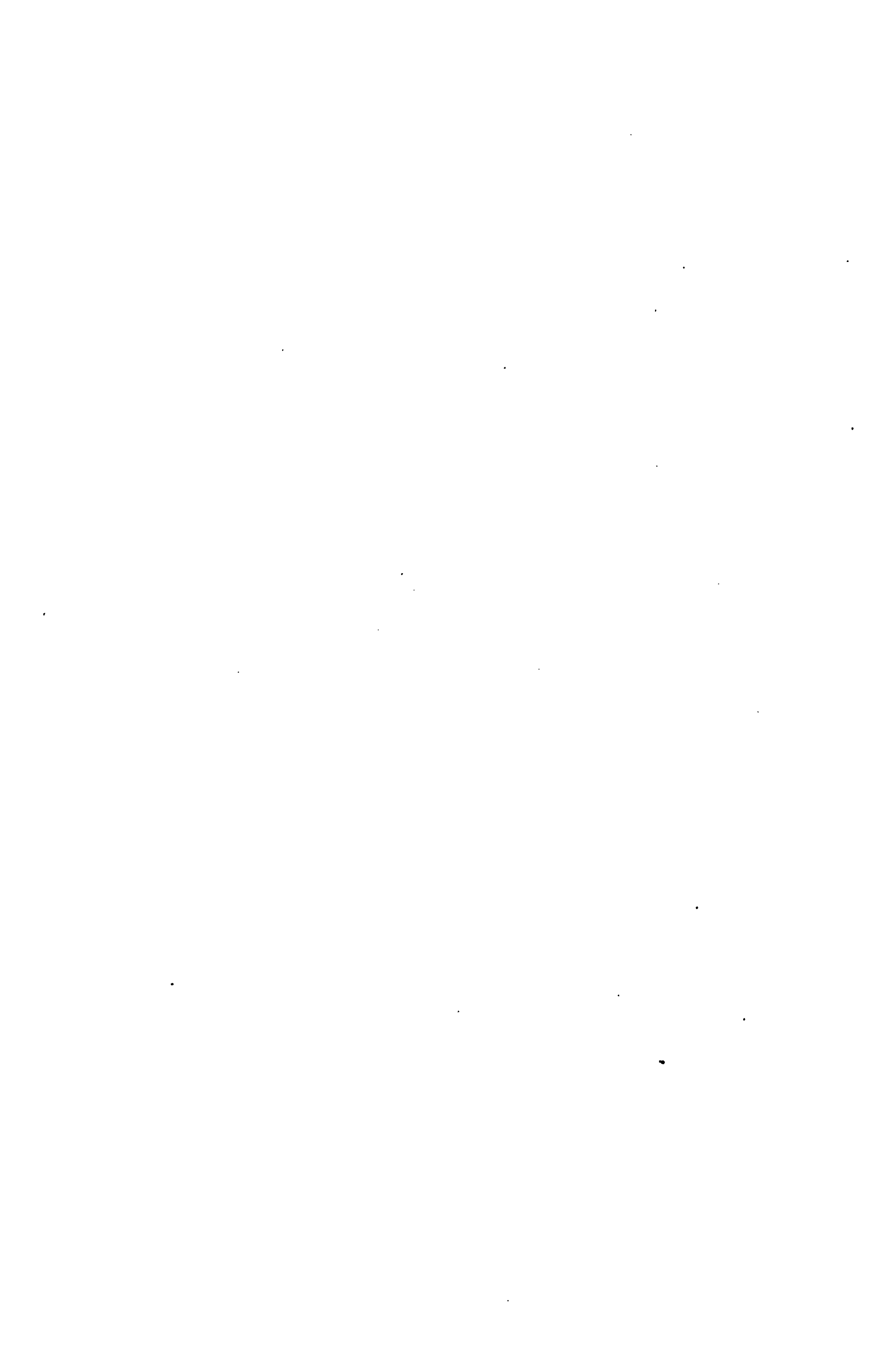


PLATE XXVII.

Cordioceras cordiforme Meek.

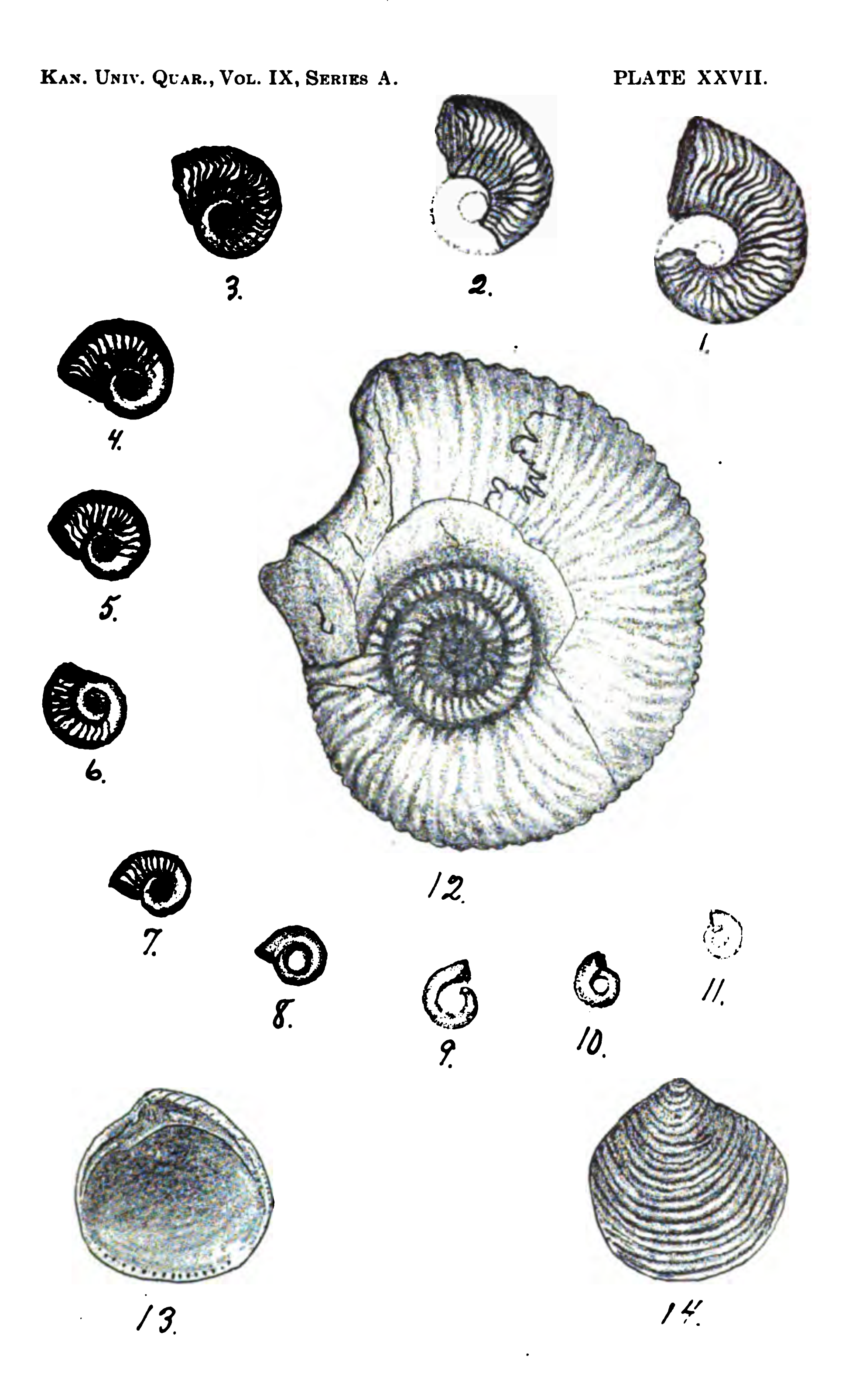
Figs. 1-11.—Views representing stages of growth.

Fig. 12.—View of adult.

Astarte packardi White.

Fig. 13.—Interior view of valve.

Fig. 14.—Exterior view of valve.


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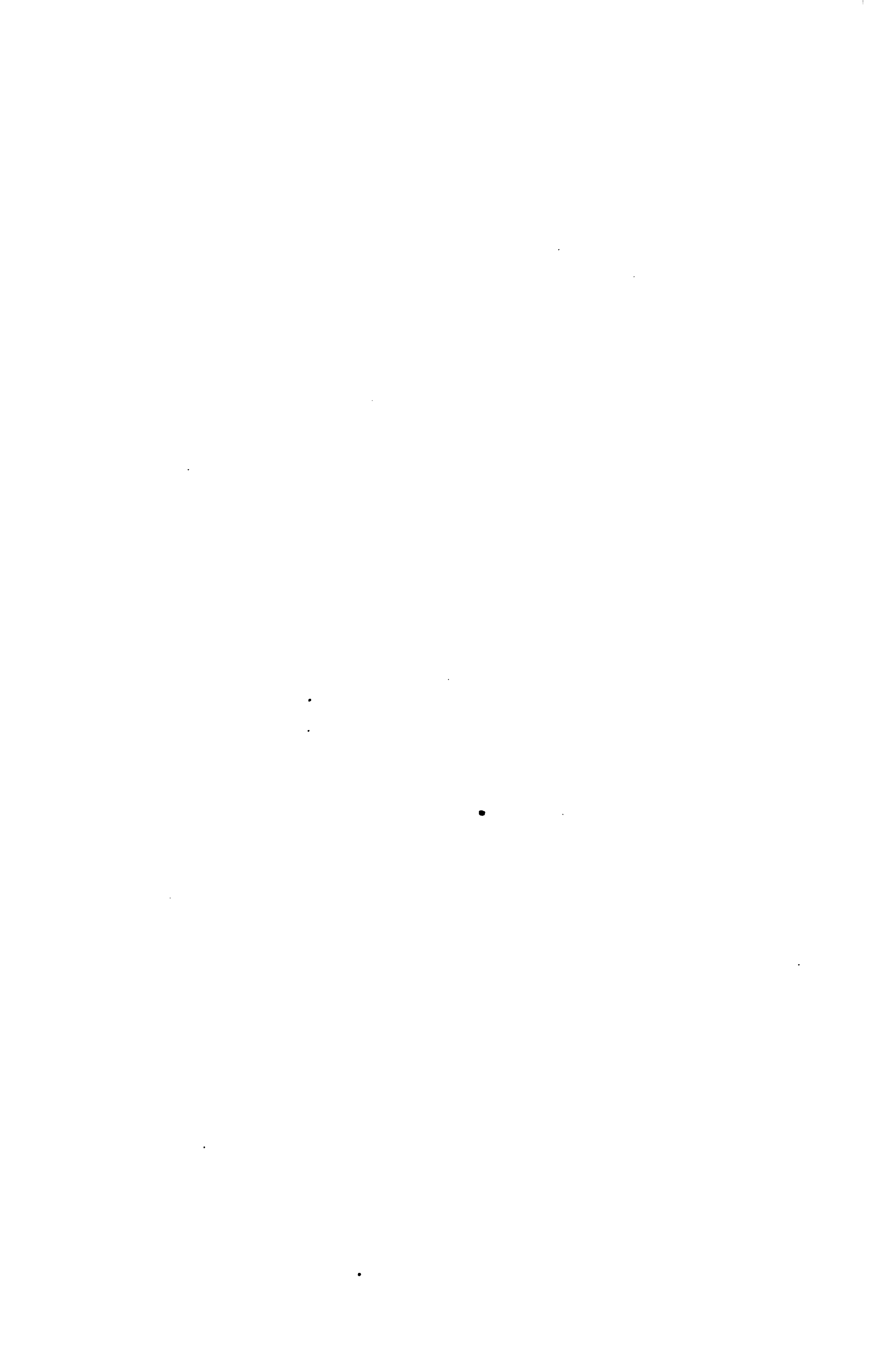




PLATE XXVIII.

Ostrea strigilecula White.

Figs. 1, 2, 5.—Views of variety I.

Figs. 3, 4.—Views of variety II.

Fig. 6.—View of variety III.

Ostrea densa, n. sp.

Fig. 7.—View of fragment, the type.

Ostrea comoensis, n. sp.

Fig. 9.—Interior view of valve.

Ostrea sp.

Fig. 8.—View of fragment.

Avicula beedei, n. sp.

Fig. 10.—Exterior view of valve.

Tancredia bulbosa Whitfield.

Figs. 11, 12.—Views of right and left valves.

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PLATE XXIX.

Pinna, sp.

Figs. 1, 2.—Views of two incomplete specimens.

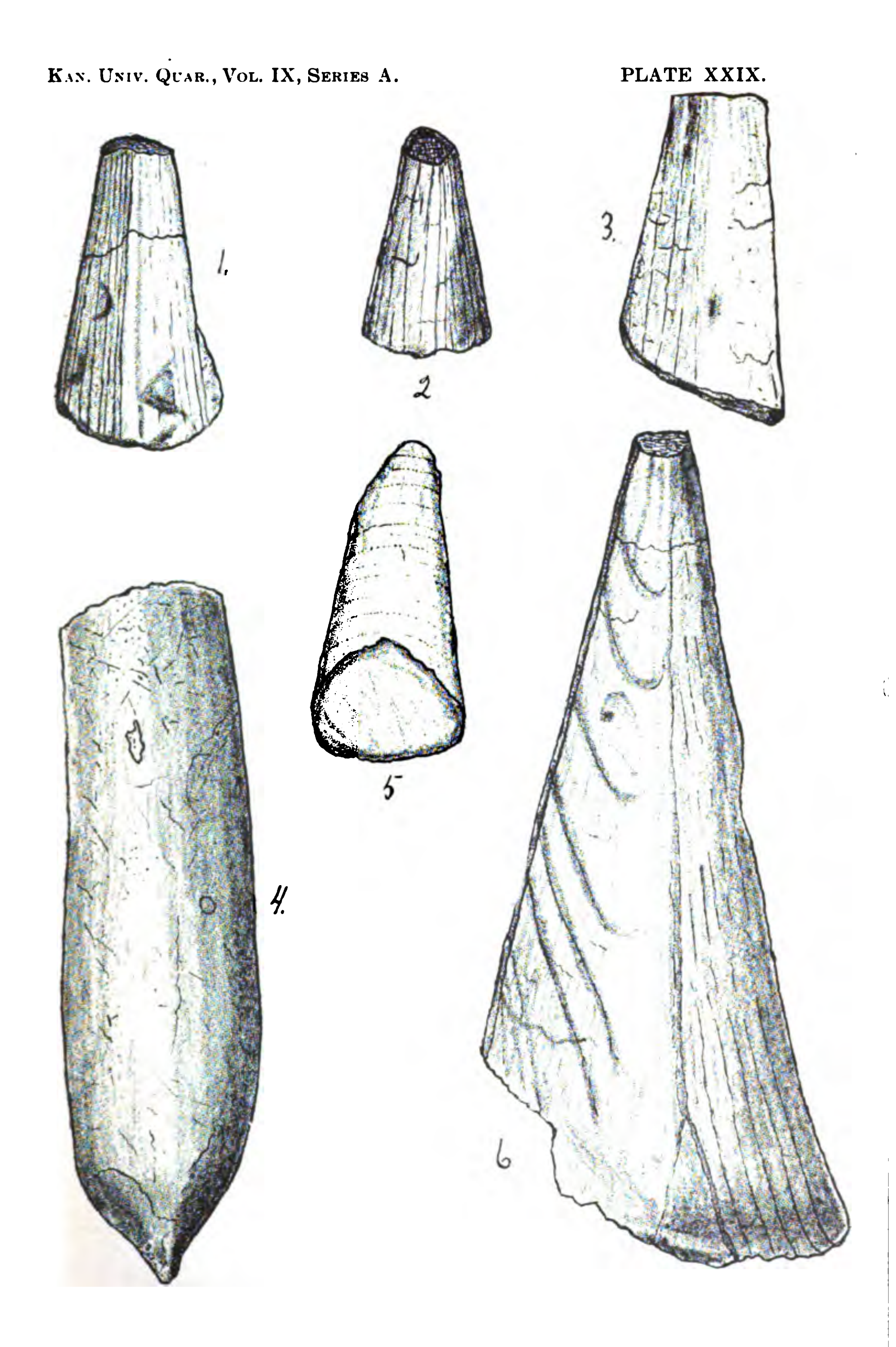
Pinna kingi Meek.

Figs. 3, 6.—The latter, a view of a nearly complete specimen.

Belemnites curtus, n. sp.

Fig. 4.—Exterior view.

Fig. 5.—Phragmacone.


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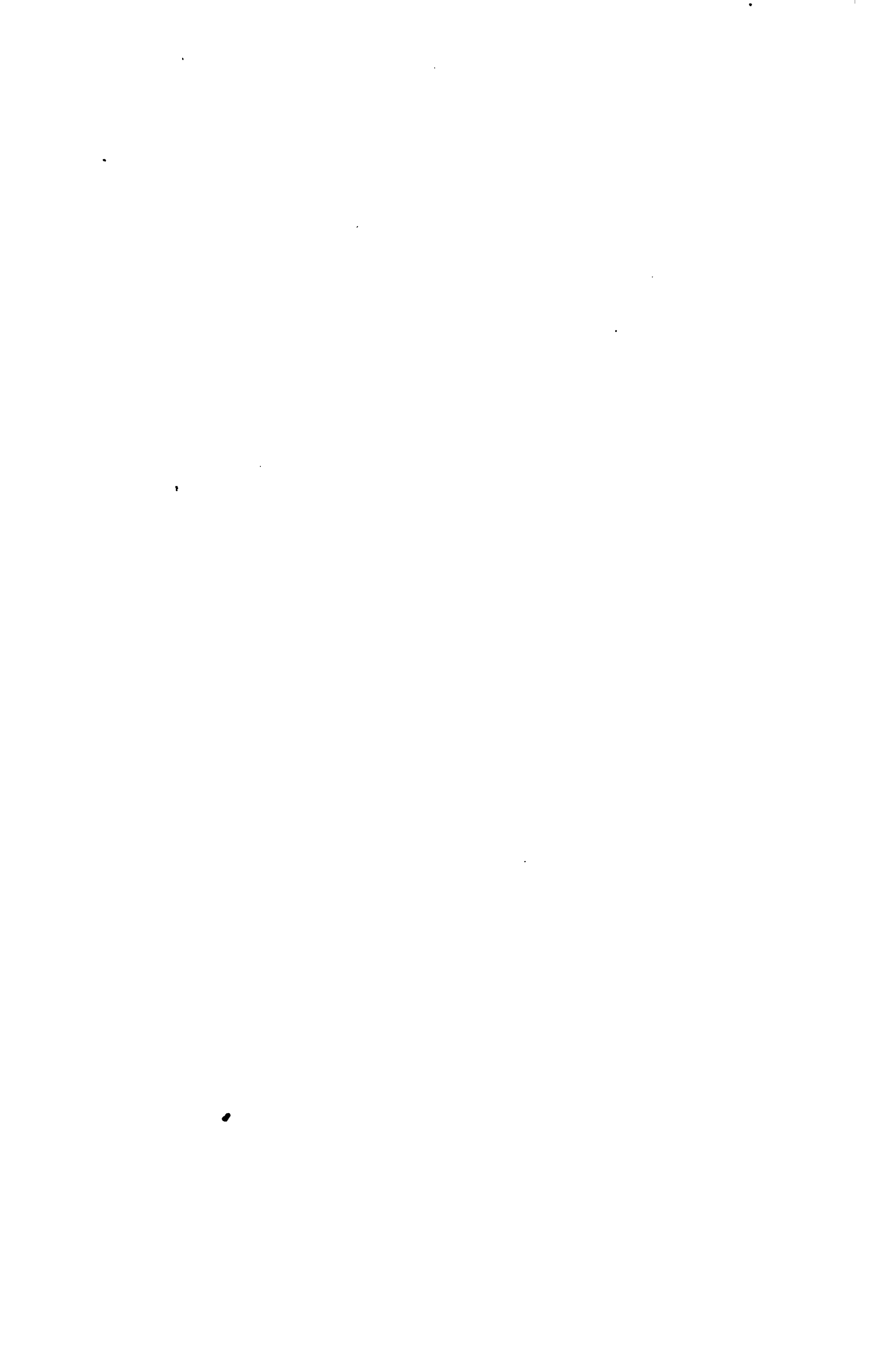




PLATE XXX.

Tancredia magna, n. sp.
Fig. 1.—View of incomplete specimen.

Lima lata ?, n. sp.
Fig. 2.—Exterior view of incomplete specimen.
Fig. 3.—Interior view of beak.

Belemnites curtus, n. sp.
Fig. 4.—Exterior view.

Pseudomonotis curta Hall.
Fig. 5.—Exterior view of left valve.

Avicula macronotus Meek.
Fig. 6.—Beak portion protuding from sandstone.

Camptonectes bellistriatus Meek.
Figs. 7, 8.—Two views of left valve.

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PLATE XXXI.

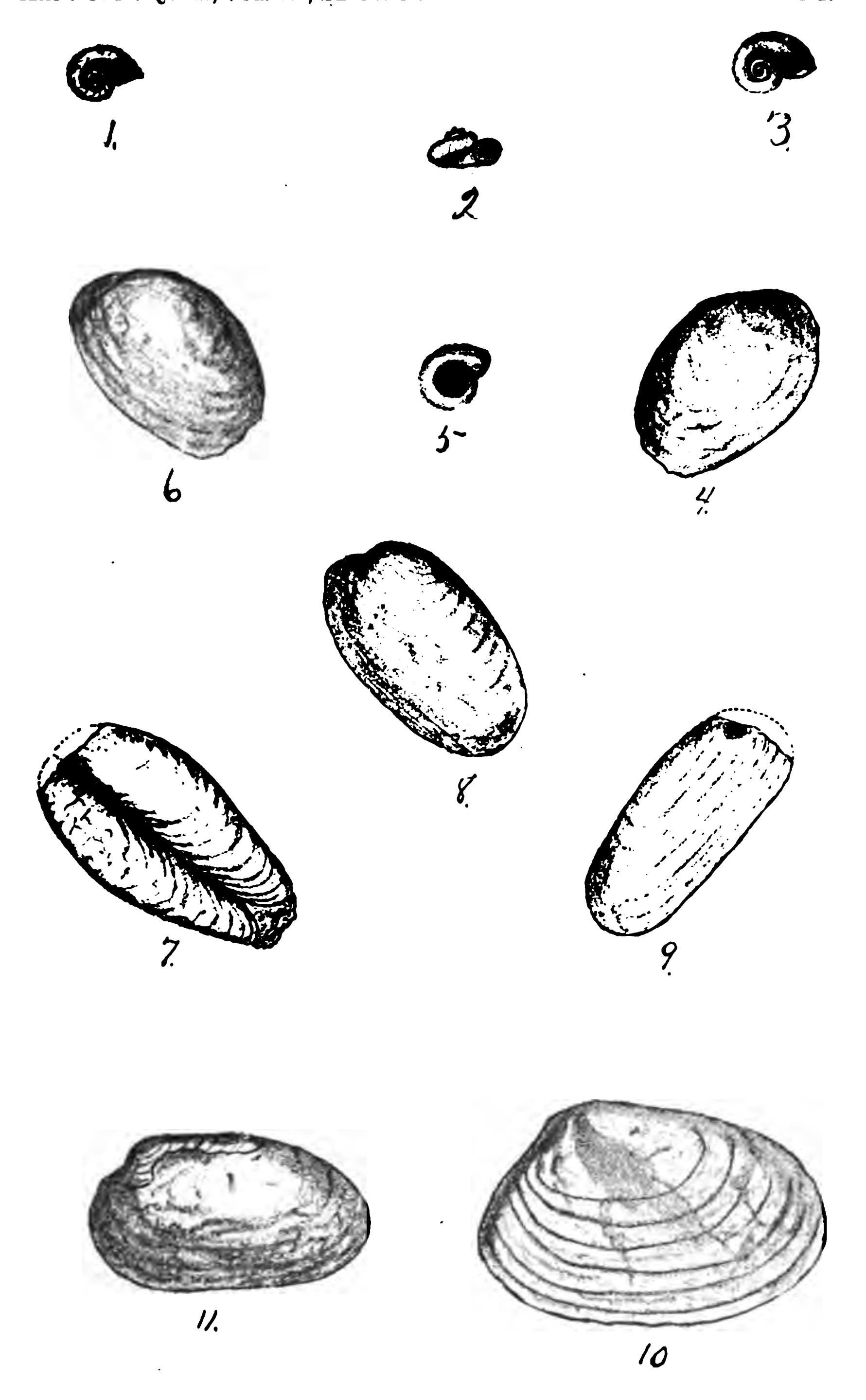
Valvata leei, n. sp.
Figs. 1, 2, 3.—Three views of shell.

Unio baileyi, n. sp.
Figs. 4, 6, 8, 11.—Views of four individuals.

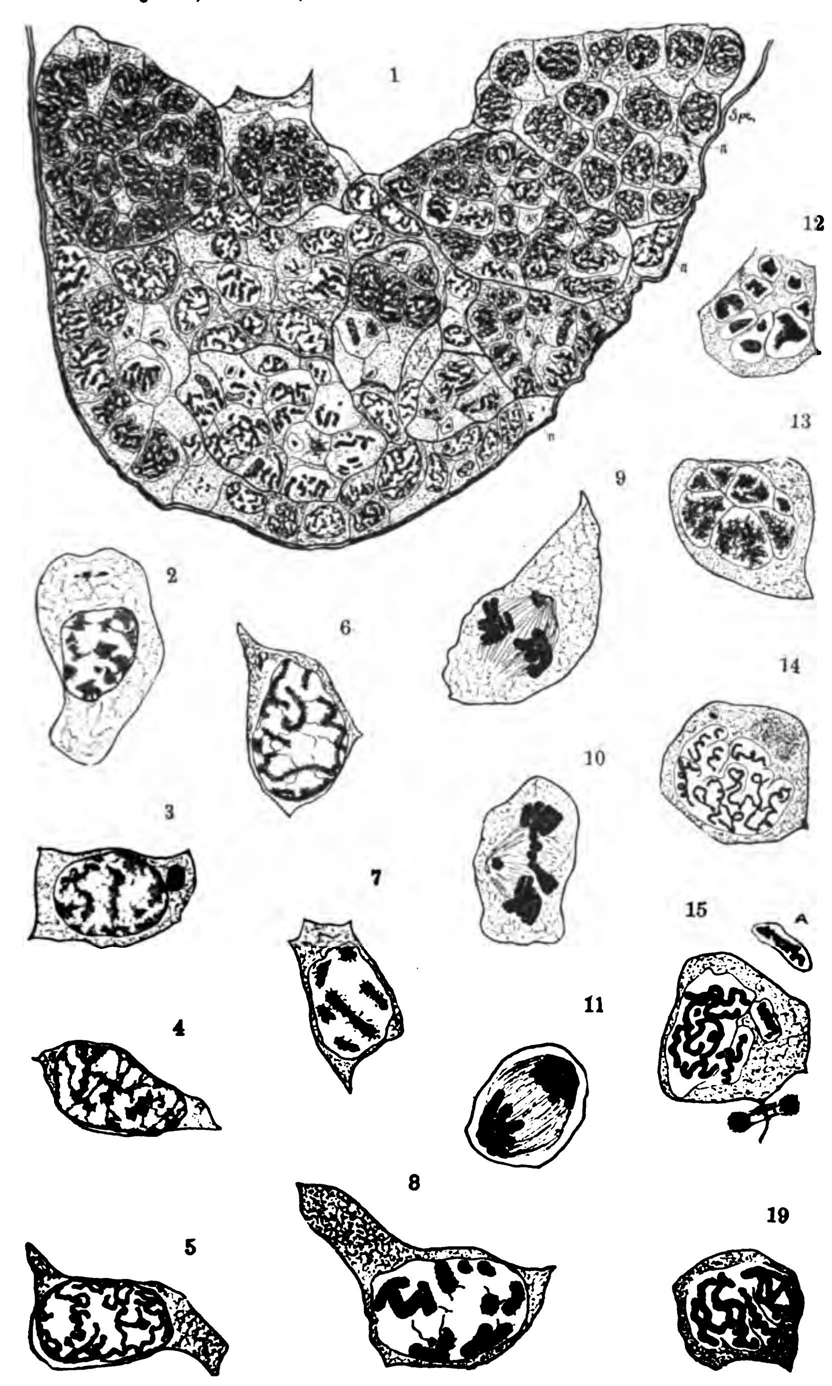
Unio knighti, n. sp.
Figs. 7, 9.—Two views of specimen.

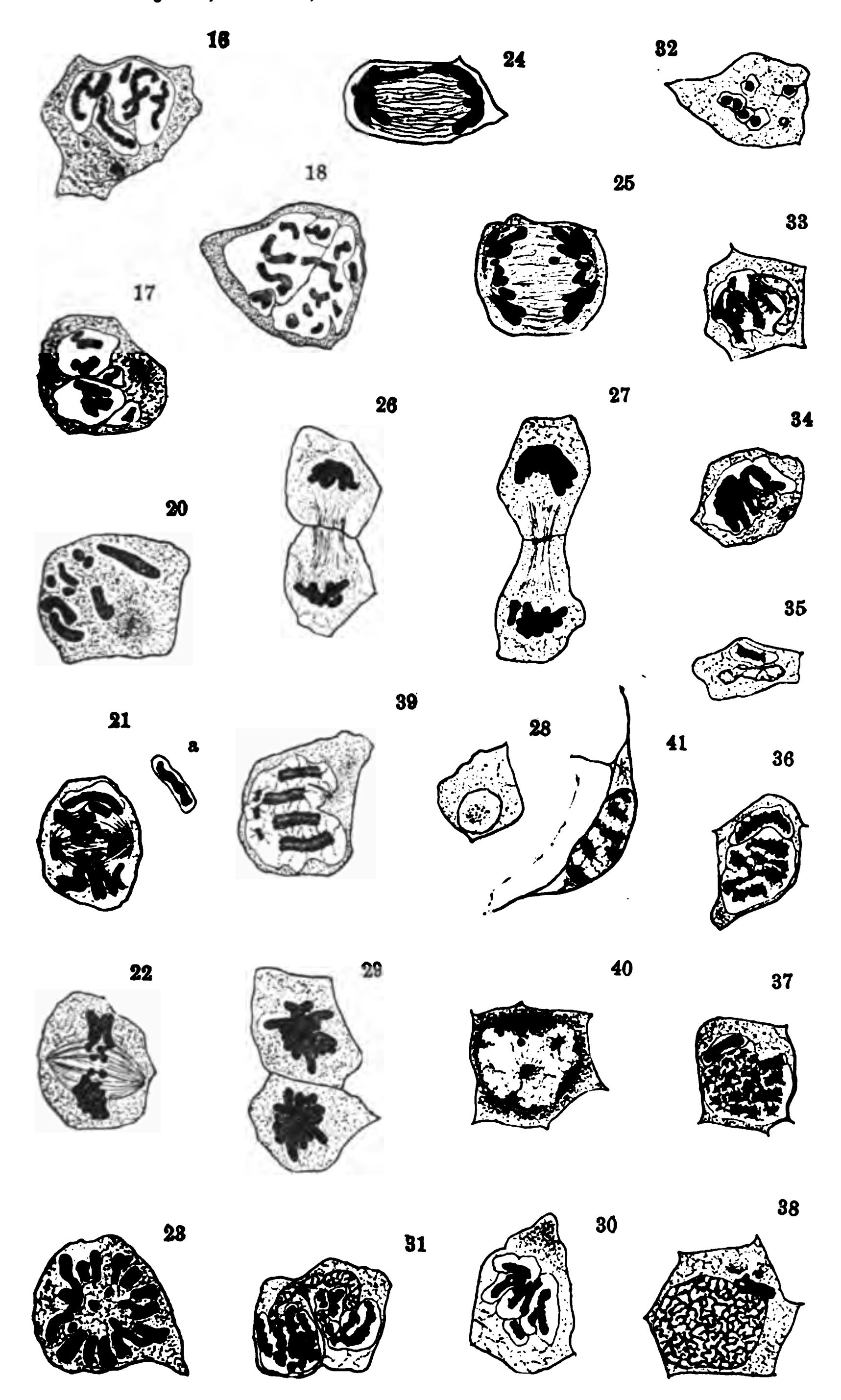
Unio willistoni, n. sp.
Fig. 10.—View of type specimen.

Planorbis veternus Meek.
Fig. 5.—Upper view of shell.

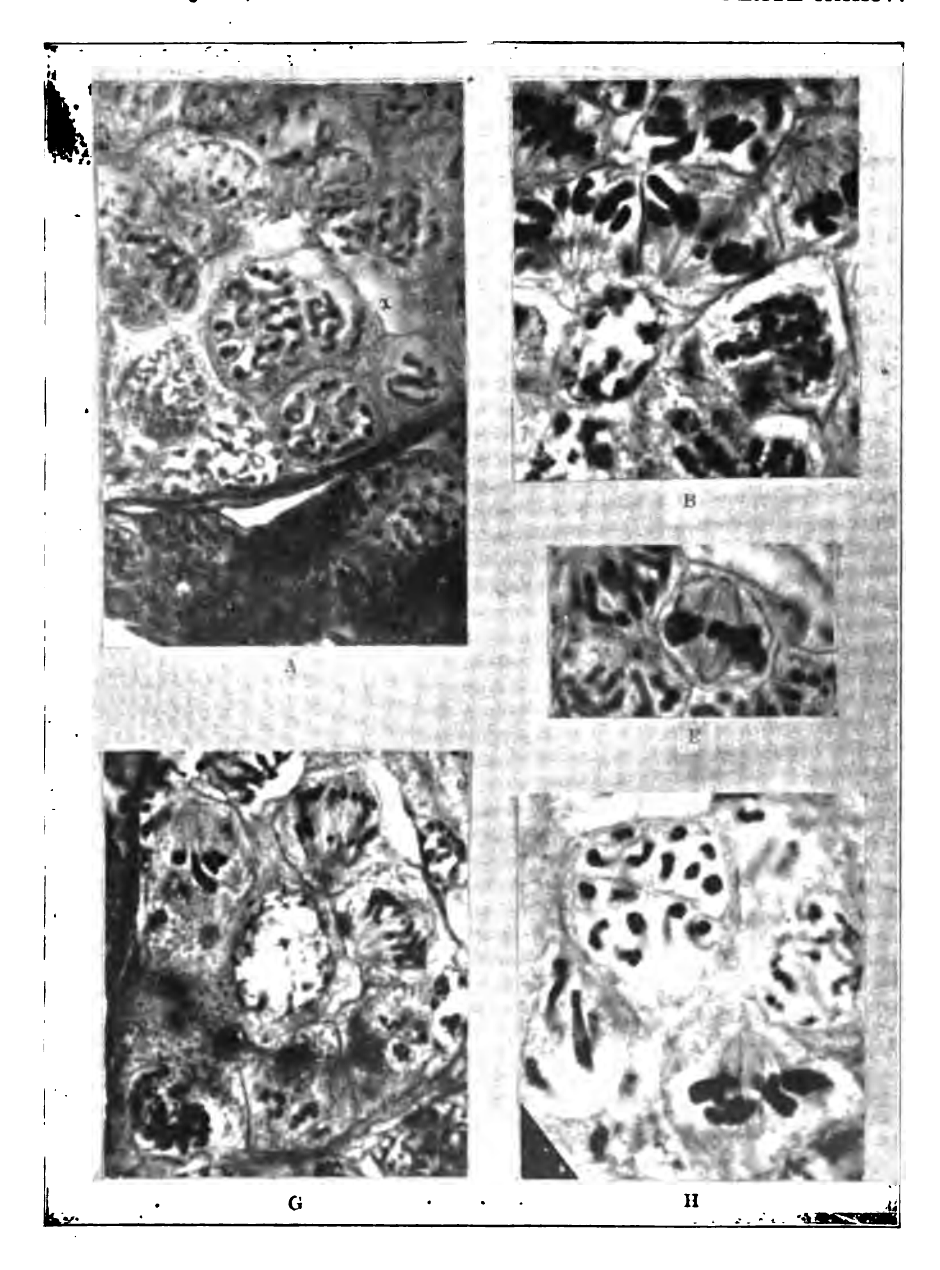

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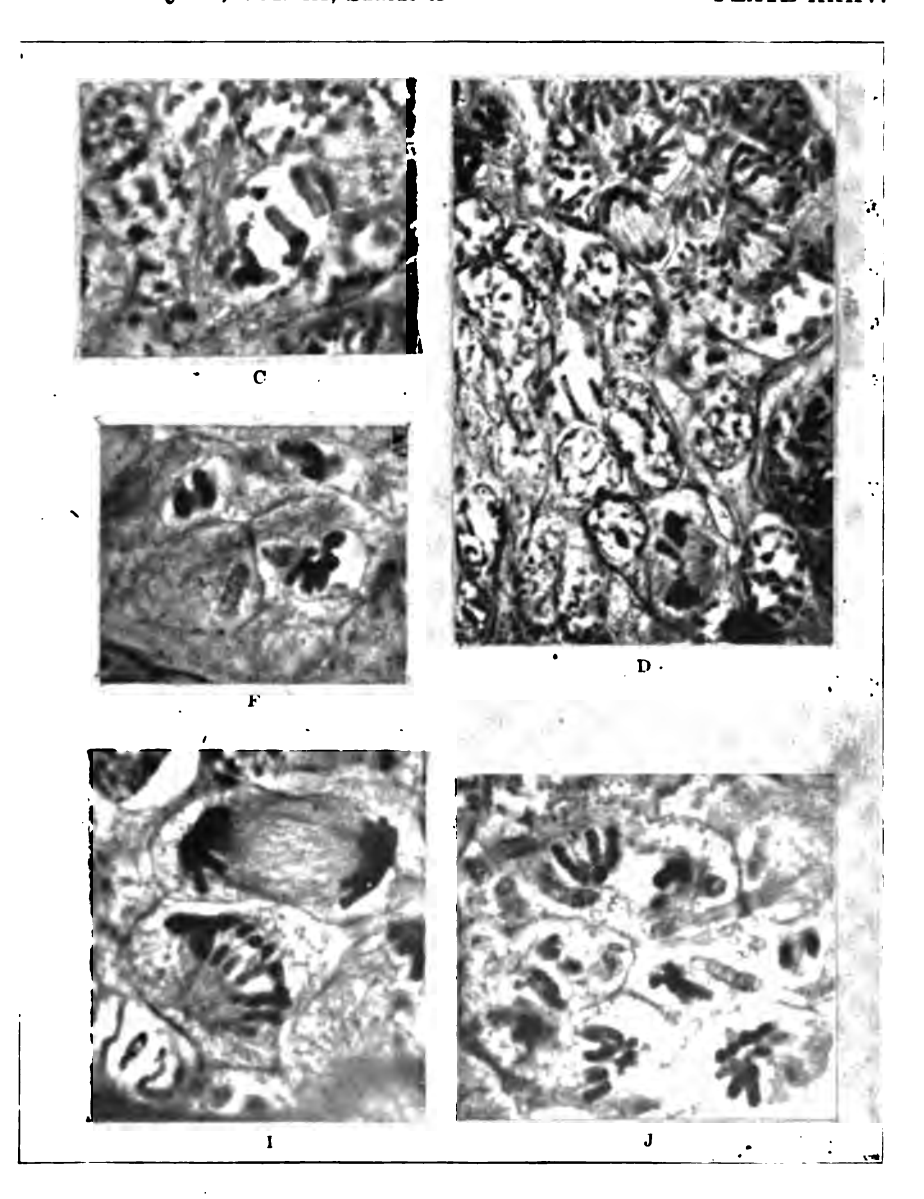

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THE

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(VOL. IX, NO. 3.—JULY, 1900.)

SERIES A.—SCIENCE AND MATHEMATICS.

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VOL. 9, No. 3. JULY, 1900. SERIES A.

COLLATERAL CIRCULATION IN THE CAT AFTER LIGATION OF THE POSTCAVA.

BY IDA H. HYDE.

With Plate XXXVI.

IN a thesis written in 1891,* I compared the azygos venous system of lower animals with that of man. It was held at that time that the azygos vein in the cat could not be traced beyond the diaphragm. In a chapter relating to the venous system, it is true, St. George Mivart, in his "Anatomy of the Cat," says that "the distribution of the azygos vein in the cat is the same as that in man." This statement is incorrect, as can be readily seen by the dissection of more than one cat, for that animal possesses only a right azygos, which, differing in its distribution more or less in almost every cat dissected, does, as my work proved, and is now stated in the last edition of Wilder and Gage's Anatomical Technology and other revised editions of anatomies, arise in the lumbar region.

The azygos vein and its branches constitute a system of great importance. It assists in maintaining the circulation through the spinal plexuses, and not only forms a connecting link between the pre- and postcava, but can, as I shall show, maintain, if necessary, the circulation of the blood throughout the body when the postcava, from pathological or other causes, is prevented from sending its blood into the heart. Inasmuch as the azygos distribution has not been described in detail in any of the text-books, I shall state its distribution in the briefest manner, to aid in a better understanding of its relation to the venous system.

* Now in the library of Cornell University.

At the base of the skull communicating branches exist between the spinal plexuses and vena vertebralis. The latter, in turn, connects through the superior intercostal with the azygos directly, or when the vertebralis and the superior intercostal are both connected with the innominate, then indirectly through it.

From the posterior region, the blood reaches the azygos through vessels from the muscles and walls of the sacral and lumbar regions that enter the spinal plexuses, and through the three commonly four-forked lumbar veins, which furthermore establish circulation between the postcava and azygos, when the latter arises from a nètwork or longitudinal vessels connecting the lumbar with each other and the spinal veins, or directly from one of the lumbar veins.

At the first lumbar vertebra, the azygos possesses a valve and enters a foramen, presenting the appearance of suddenly coming to a limit. It receives, however, among others, tributaries from vessels of the diaphragm, adrenal, ileo-lumbar, intercostal, and often a large vein from the first lumbar.

It is evident that the postcava and azygos are mutually dependent and supplementary, and that if for any cause the postcava should be obstructed anywhere in its course, the blood would be returned to the heart by the azygos through the intervention of the lumbar veins and spinal plexuses. The latter practically establish communication between veins of the body throughout the extent of the spine.

It was of interest to test the correctness of this assertion; then, too, the facts connected with such an operation seemed sufficiently important to warrant its undertaking.

The first experiments were performed on kittens two days old. It was thought that animals at this period of growth, with immature arrangement of vessels connecting with those of the liver, would more readily adapt themselves to the altered conditions introduced by the experiment. On the other hand, the chances of keeping them alive are lessened even by feeding them with warm sterilized milk. In regard to this question, however, too few operations were made on such young kittens to justify drawing a definite conclusion.

From a litter of four kittens three days old one was kept for a control experiment; the remaining three were anæsthetized,

kept warm, and operated on with aseptic precautions. An incision was made to the right of the median abdominal wall, the intestines laid out on warm, moist, sterilized cotton, and the postcava exposed. It was ligated anterior to the entrance of the right renal vein, the wound sewed, and covered with collodion. Within four days the kittens were dead. The *post mortem* showed that peritonitis had set in, but a comparison of the blood-vessels with those of the unoperated kitten showed differences which encouraged the continuation of the investigation.

Kittens a few weeks older were similarly operated on, and all died within four days from peritonitis (purulent?). The remaining experiments were performed on older kittens, with greater aseptic precautions. I shall describe the condition of one of those that had the postcava ligated below the liver, about one centimeter anterior to the entrance of the right renal vein, and which gave successful results.

On March 27 I operated on a young cat that had not been fed for sixteen hours. During the two days that followed the cat remained inactive, sleeping most of the time, and refused food. The third day it walked slowly about and lapped milk. The seventh day it was more active, but its walk was abnormal; the hind legs were not raised from the ground, but dragged along; this was, no doubt, due to the wound and to the altered circulation. At the end of the second week it ran actively about and seemed quite normal in every respect, and the wound had entirely healed.

Four weeks after the operation, the animal was chloroformed, its venous system injected with colored starch, from the femoral vein, and compared with that of a normal cat of equal proportion likewise injected. In comparing the venous system of the operated cats with that of the unoperated, the most striking differences were the great increase of small vessels in the ligated area, the large size of the lumbar, ileo-lumbar, adrenal, superior intercostal, azygos and two longitudinal intraspinal or meningo-rachidian veins.

The cavity of the postcava was obliterated by the growing together of the walls at the place of ligation. Some small anastomosing vessels had developed between the postcava anterior and posterior to the ligature, between the postcava and the

adreno-lumbalis, the right renal and adrenal, left renal and postcava, and the lumbar azygos and adrenal. (See plate XXXVI, *b*, *m*.)

The adreno-lumbalis of the right side emptied into the postcava one centimeter above the ligature. It was very large, as was also the ileo-lumbalis, which sent numerous tributaries to the lateral abdominal wall and psoas muscles, some of its branches opening into the postcava below the ligature, others into the iliac and ascending vessel that gave rise to the azygos.

On the left side several large branches arose from the adreno-lumbalis, which connected on this side with the renal vein. The largest of its branches extended anteriorly along the side of the wall, to empty into the azygos near the first lumbar. Another vessel that emptied here was distributed in the diaphragm; while others that are found in the lateral wall connected with the postcava above the ligature.

Near the heart the azygos was about four-fifths the size of the postcava, while in the normal cat it is from one-half to two-thirds the size. The four lumbar and superior intercostals were larger than normal.

From a study of the changes instituted by the ligation of the postcava, there seems to be a tendency to establish connections between the two parts of the cava separated by the ligature. This is seen in the development of the numerous tortuous anastomosing vessels between the separated parts as well as between branches of vessels that empty into them. It requires further study to determine whether these vessels developed from capillaries into veins, or arose as new tributaries from existing veins.

It is seen, moreover, that the tendency is to return the blood to the heart through the most direct path of least resistance. The blood entering the postcava below the ligature passes through the lumbar veins into the spinal sinuses and origin of the azygos vein, or directly, from the postcava through the lumbar veins to the azygos. Then, too, the paths conveying blood from other abdominal regions to the thoracic azygos we saw were strengthened. It is evident that the azygos has risen in importance, receiving now from all possible directions most of the blood that is to be returned to the heart from regions below the ligature.

The vessels that appeared in the ligated area and anastomosed between veins that carry blood directly and indirectly to afferent paths may owe their origin to local pressure. We should expect that under this condition there would be a greater flow in certain directions, causing an enlargement of the paths of those channels, and that this in turn would influence, with the rise of pressure, a thickening of the walls of the smallest vessels. This would be in harmony with the laws formulated by Thoma,* in his study of the development of blood-vessels.

When the anastomosing network of vessels of the ligated postcava and its tributaries increased, the pressure lowered, and the flow in that direction became more rapid. In consequence of this the caliber of the azygos and its tributaries increased.

The results of these experiments prove that in all cases where the blood-flow through the postcava has been hemmed by pathological growths that compressed the vessel, or, where it is necessary, due to accident or operation, to obstruct the flow through it, the normal activities of the body will not be materially impaired if the paths leading to the azygos and through it to the heart are not interrupted.

In cases of atrophic cirrhosis of the liver, where the blood-flow from the vena porta is prevented by compression of the blood-vessels in the liver, collateral circulation was first established by Talma.† He caused adhesion between the abdominal wall, the liver, spleen, and omentum. The blood reached the postcava partly from anastomosing networks of vessels developed in the adhesive region, the hypogastric, and femoral. Survival would, I should think, be possible even if under such circumstances the postcava in the region of the liver were so compressed by the disease as to stop the flow through it, provided the passage through the azygos and its tributaries in the abdominal region were kept open.

* Thoma: Untersuchungen über die Histogenese und Histomechanik des Gefässystems. Stuttgart, 1893.

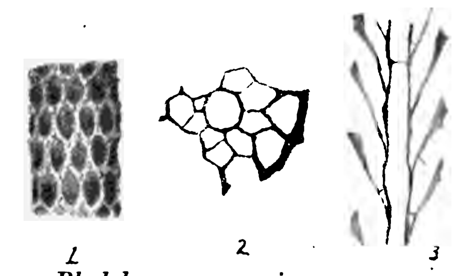
† S. Talma chirurgische Oeffnung neuer Seitenbahnen für das Blut der Vena Porta. Berliner Klinische Wochenschrift, 1898.

OCCURRENCE OF THE BRYOZOAN GENUS RHABDOMESON IN AMERICA.

Contribution from the Paleontological Laboratory No. 56.

BY AUSTIN F. ROGERS.

THE genus *Rhabdomeson* Young and Young, heretofore unknown in this country, is represented in Great Britain by two species—*R. gracile* Phill. and *R. rhombiferum* Phill. In 1884 Ulrich wrote as follows: "Species of *Rhabdomeson* have not yet been detected in this country, but a closer search in our carboniferous deposits will, I feel convinced, bring them to light."* This prediction has been realized, for the author has recently found undoubted members of this genus in the Coal Measures of eastern Kansas and western Missouri. Transverse and vertical sections of the specimens exhibit the central tubular axis, in which single character *Rhabdomeson* differs from *Rhombopora*. Our specimens belong to a new species, which is here described.



Rhabdomeson americanum, n. sp.

1. Portion of a stem, showing surface characters, × 20.
2. Transverse section, × 35.
3. Vertical section, × 20.

Zoarium a slender cylindrical stem, 0.5–0.6 mm. in diameter, throwing off at unknown but distant intervals branches at nearly a right angle from the main stem. Zoecial apertures comparatively large, elongate-oval or elliptical, but, on account of the ridge-like interspaces, they have a decided hexagonal

* American Paleozoic Bryozoa, E. O. Ulrich, Journal of the Cincinnati Society of Natural History, vol. VII, p. 24, 1884.

appearance. Apertures arranged in quite regular longitudinal, transverse and diagonally intersecting series. It requires about ten or twelve rows to encircle the stem. Measuring longitudinally, two apertures occur in a space of 1 mm.; diagonally, three in 1 mm. The interspaces are comparatively narrow, and a small acanthopore is placed at their junction angles. The zoecial tubes arise from a central axial tube and approach the surface gradually, so that the apertures, especially in slightly worn specimens, are deeper at the posterior end than at the anterior end. An occasional diaphragm is observed in both the central tube and the zoecial tubes.

Position and locality: Upper Coal Measures; Lower Oread limestone at Lawrence, Kan., associated with the following species of bryozoans: *Fistulipora nodulifera* Meek, *Rhombopora lepidodendroidea* Meek, *Streblotrypa ulrichi** Rogers, *S. striatopora** Rogers, *Cystodictya inequimarginata** Rogers, *Fenestella kansasensis** Rogers, *F. limbata* Foerste, *F. remota* Foerste, *F. shumardi* Prout, *Polypora elliptica** Rogers, *P. flexuosa?** Rogers, *P. submarginata* Meek, *P. triangularis** Rogers, *Thamniscus tenuiramus** Rogers, *Pinnatopora ptiloporoidea** Rogers, *P. trilineata* Meek, *P. whitii* Foerste, *Septopora biserialis* Swallow, *Rhombocladia delicata** Rogers, and an undescribed species of a new genus belonging to the *Phylloporinidæ*. Also found in the Iola limestone at Kansas City, Mo., and at the summit of the Upper Coal Measures in the Cottonwood Falls limestone at Cottonwood Falls, Kan. Type in the author's collection.

Our species differs from *R. gracile* Phill. in the shape of the apertures, in the number and distribution of acanthopores, and in having a fewer number of apertures which occur in a given space. This species bears a strong resemblance to some species of *Rhombopora*, and it is almost impossible to identify it by external characters. Thin sections, always valuable adjuncts in the study of any fossil bryozoans, are here necessary. Small ramose forms, with thin interspaces and with the zoecial tubes approaching the surface gradually (very noticeable in worn specimens) are apt to belong to this species, and may be further studied by means of thin sections.

UNIVERSITY OF KANSAS, Lawrence, May 31, 1900.

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* The starred species were described by the author in the Kansas University Quarterly, vol. IX, pp. 1-12, pls. i-iv, 1900, series A.

STRATIGRAPHY OF THE McCANN SANDSTONE.

BY C. N. GOULD.

IN July, 1897, while on a reconnaissance trip through Kay county, Oklahoma, my attention was called to a number of small fossil invertebrates in the red sandstone that was being placed in the foundation of a house. On inquiry, I learned that the rock came from McCann's quarry, on Deer creek, about twelve miles southwest of Blackwell. Although recognizing the value of the discovery of fossils in the Red Beds, on account of the lack of time I was unable to visit the quarry. A number of fossils were obtained and sent to Professor Prosser, who kindly undertook their identification.

In March, 1898, by the advice of Professor Prosser, I made a trip to the quarry. Although my visit was necessarily hurried, in addition to the invertebrates, which are found in great numbers, I secured a small quantity of vertebrate material, consisting of teeth, scales, and bones. This was sent to Doctor Williston. A general survey of the locality was made—enough to satisfy me that the quarry was located near the base of the Red Beds, but no accurate sections were taken.

It was not until the latter part of July, 1898, that I was permitted to make a thorough examination of the locality. By the kindness of Doctor Williston, I was enabled to spend several days in the vicinity. On this trip I was accompanied by Mr. Mark White, an enthusiastic scientific student of Southwest Kansas College. Mr. White rendered valuable service while in the field. Some of the best finds were the result of his perseverance.

Deer creek is tributary to the Salt Fork of the Arkansas, twelve miles southwest of Blackwell. The creek is a typical prairie stream. In its upper course it is fed by Tertiary springs. The slopes are in most places gentle. On the south side of the creek, for a distance of four or five miles, a steep bluff is capped by a ledge of dark red or mottled sandstone from two to five feet thick. In this sandstone on several farms quarries have been opened. The most important of these are on the farms of

Messrs. McCann, Davis, and Mahaffy. The rock quarries into good dimension stone, and supplies the local demand for a distance of fifteen or twenty miles. Several business blocks in Blackwell are built of the stone from these quarries.

The following sections, illustrative of the character of the rock both below and above the ledge, were taken in the vicinity.

SECTION No. 1.—The lower part, to No. 14, taken on D. Campbell's farm; the remainder at Jones's butte, one mile east of McCann's quarry:

No.		Feet.	
21.	Butte capped with two feet of massive red sandstone (the McCann)	2	79
20.	Arenaceous red shale	6	77
19.	Soft gray limestone, in blocks	½	71
18.	Red clay	4	70½
17.	Blue clay shales	4	66½
16.	Red clay	3	62½
15.	Bluish shale with bands of red	6	59½
14.	Hard grayish limestone, forming escarpment	½	53½
13.	Reddish and bluish shales	7	53
12.	Rather hard grayish limestone, forming escarpment	½	46
11.	Bluish and greenish shales	3	45½
10.	Several layers of limestone one inch thick, in blue shale	1	42½
9.	Blue shale with green and red bands	11	41½
8.	Red clay	5	30½
7.	Bluish limestone	½	25½
6.	Bluish clay with red streaks	3½	25
5.	Shaly gray limestone	½	21½
4.	Blue clay	1½	21
3.	Soft white limestone	½	19½
2.	Red and green clay	4	19
1.	Covered slope from creek	15	

SECTION No. 2.—Four miles northwest of McCann's quarry and one mile north of the post-office of Osborne. The base of the section is probably not to exceed twenty feet above the McCann sandstone:

No.		Feet.	
10.	Red soil and gravel resting unconformably on No. 9 (Pleistocene),	8	29½
9.	Red clay	3	21½
8.	Blue clay	¾	18½
7.	Red clay with bands of blue	8	17¾
6.	Rather hard white limestone	¼	9¾
5.	Red clay	2	9½
4.	Blue and green shale	½	7½
3.	Red clay	3	7
2.	Thin layer white limestone separated by shale	1	4
1.	Hard red clay in creek bed	3	

At this point the strata are exposed for more than 100 yards along the bluff. In this distance, four distinct faults are noticed. The strata have slipped from one to three feet.

The dip of all the strata seems to be to the southeast.

A comparison of sections No. 1 and No. 2 will show that

No. 1, taken below the sandstone, consists chiefly of blue shale, with occasional strata of white limestone and red shale, and that the red shale becomes more frequent towards the top; also, that in No. 2, taken above the sandstone, the blue shale has been replaced by the red. In ascending the hills to the west, above section 2, the whole country is red, the blue shale having almost entirely disappeared. The color of the soil in this locality reminds one of Barber or Harper county, Kansas.

These considerations would seem to indicate that the sandstone mentioned marks the dividing line from the blue to the red shales, or from the Wellington to the Harper.* Although red shales are found in the Wellington and Marion (Geuda),† and even in the Chase,‡ it is not until the disappearance of the blue shales that the term "Red Beds" is applicable.

For this sandstone the provisional name of *McCann* sandstone is proposed, from the name of the quarry where the ledge was first studied and which has been most prolific in fossils. This is intended not as a formational name, but simply as the local name for the lower ledge of the Harper formation of the Cimarron series. This ledge, so far as I know, has no counterpart in Kansas. The first sandstones of the Harper hard enough to quarry, near the towns of Harper, Spivey, Kingman, and Arlington, are nearly 100 feet above the base of the formation.

The McCann quarry is located on the farm of Mr. T. W. McCann, eight miles west and four miles south of Blackwell, O. T., nineteen miles south of Hunnewell, Kan., on the southwest quarter of section 9, township 26, range 2 west. The nearest railroad station is Nardin, four miles northwest.

On one trip Mr. White and I were successful in securing a number of invertebrates and portions of the skeleton of a large reptile; also, fossil leaves (ferns) and stems from the sandstone. Other reptilian bones have been discovered in different parts of the quarry, but most unfortunately they have been carried away and lost.

SOUTHWEST KANSAS COLLEGE, Winfield, August 20, 1898.

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* Colorado College Studies, vol. VI, p. 3.

† l. c., pp. 12, 18.

‡ This journal, vol. VI, No. 4, Oct., 1897, p. 168.



A NEW GENUS OF FERNS FROM THE PERMIAN OF KANSAS.

Contribution from the Paleontological Laboratory, No. 57.*

BY E. H. SELLARDS.

With Plates XXXVII-XLII.

THE plants described in this article come from a locality three and a half miles south of Banner City, Dickinson county, Kansas. Three lots of plants have been collected—the first by Mr. Sterling, of the University, in the summer of 1899; the second by the author, in October of the same year; and the third, also by the author, in September of the present year. The plants are preserved in an impure, more or less concretionary limestone, sometimes grading into a sandstone. The horizon bearing the plants is within about twenty feet of the top of the highest Permian in that region, the hill along the side of which the plants are found being capped with Cretaceous sandstone. The types of all the species described are in the museum of the University of Kansas. The specimens figured, when not otherwise stated, are those collected by the author. All discussion of the geological age of the formation, as well as the extent and character of the plant-bearing horizon, is deferred until the completion of the author's report on the entire collection. The drawings and photographs are by the author.

I am indebted to Dr. S. W. Williston for permission to work on the Permian plants and for advice in the preparation of this article. I am also indebted to Dr. David White, of the United States Geological Survey, for advice and for personal favors; and to other officials of the U. S. National Museum, for access to paleobotanical library and plant collections of the museum during a part of the past summer.

* Published by permission of the Paleontologist of the University Geological Survey of Kansas.

GLENOPTERIS, gen. nov.

Fronds pinnatifid, or simply pinnate, elliptical in outline, tapering to base and apex. The fronds of the different species of the genus have a very considerable range in size, from 10 to 15 cm. for the smallest species to 45 cm. or more for the largest. Base always petiolate; rachis strongly developed, proportionally strong at the base, longitudinally striate. Fronds, apparently thick and fleshy in life, leaving a carbonaceous layer on the rock, in which the veins are deeply emersed, and often hidden. Pinnules attached to the rachis by the entire base, decurrent, or auricled below, more or less rounded above. Pinnules at the base of the frond reduced, open, or more commonly reflexed. Those at the middle of the frond largest, varying in size and shape with the size of the frond, oblong to linear, oblique, or curved back at the apex. Borders entire or undulate, and even lobate in one species referred doubtfully to the genus. Pinnules towards the apex also reduced, becoming more ovoid, even odontopteroid in appearance, ending in undulations of a terminal pinnule. Midvein of the pinnule strong in the large fronds, percurrent at the base, running some distance down the rachis before uniting with it, continuing to or near the apex. Lateral veins oblique, rather thin, and often obscured by the thick frond; simple or forking, basilar attached to the main rachis; curved in passing to the border, or almost straight. The decurring wing, or auricle, receives numerous strongly curved, or straight, simple, or forked, nerves from the main rachis. Fructification unknown.

The plants of this splendid genus are among the most abundant of the formation. Four well-characterized species have been found, represented by good specimens, and one specimen of a fifth species doubtfully referable to the genus. In addition, there are two specimens in the collection, one the apical part of a frond, the other a young frond still in the circinate condition at the apex, which apparently are not referable to any of the species described. The pinnules of both are linear, very acute, straight, and oblique to the rachis. The numerous individuals, and the differentiation that the genus has reached, indicate that it was a leading genus in the flora of the formation. In a note on the Permian Flora of Kansas, Kansas University Quarterly, vol. IX, p. 64, the author referred to this group of plants as

herbaceous ferns. The large fronds now at hand, having a strong rachis broken off short at the base, make it more probable that the fronds are detached from the upright, more or less arborescent stem. It seems even possible, but not probable, that we have here only the ultimate division of larger fronds.

Generic relation.—Among Paleozoic plants, the genus most closely related to ours in the form and development of the frond is *Protoblechnum* Lesqx. The type, and only species known of this genus, comes from near the base of the Coal Measures, Rushville, Ohio, and was first described as *Althopteris holdeni* by Andrews.* Lesquereux afterward made Andrews's species the type of the genus *Protoblechnum* Lesqx. *P. holdeni* (And.) Lesqx. has, like the species of *Glenopteris*, sessile, auricled pinnules, reduced at the base of the petiolate frond. The estimated length of this species, 50 to 60 cm., is only slightly larger than that of the largest species of *Glenopteris*. The apical part of the frond of *Protoblechnum* differs, however, entirely from that our genus. In the several species of *Glenopteris* the pinnules are reduced gradually towards the apex of the frond, at last uniting with a terminal pinnule. The frond of *Protoblechnum* is represented as ending abruptly, the pinnules not at all reduced. It might be suspected that the apex of the specimen was gone, especially as the rachis continues moderately strong to the very last, were it not that both authors agree in describing the frond as complete. Lesquereux says (Coal Flora, p. 188): "The upper ones (pinnules) are close, less distinctly scythe-shaped, but quite as long, the terminal leaflets being still 6 cm. long." The venation of *Protoblechnum* Lesqx. is apparently distinct, the veins twice forked; the venation of *Glenopteris* is indistinct, and often obliterated, the veins simple or forked once. The thick coating of scales on the rachis of *Protoblechnum* is a minor character not seen on any species of *Glenopteris*.

Glenopteris cannot be closely compared with any other genus of Carboniferous ferns. It has, however, in the sessile decurrent pinnules, a general relation to all the genera of the alethopteroid group, to which it accordingly finds its most natural reference. The relation after *Protoblechnum* Lesqx. is perhaps closest to *Alethopteris* St. But the genus differs from all the other *Alethopterids* again excepting *Protoblechnum*, in the sim-

*Geol. Survey of Ohio Pal., vol. 2, p. 420, pl. LI, figs. 1–2a.

ple fronds and large pinnules. The apices of the fronds of *Glenopteris* have a peculiar resemblance to *Odontopteris*. So striking is this resemblance in *Glenopteris simplex*, that the apex, if found detached, unassociated with the rest of the frond, would probably be taken for a large *Odontopteris;* but the frond as a whole is very different from that genus. There is a resemblance perhaps worth noting between *Glenopteris* and the smaller species of *Megalopteris* Dawson in the sessile decurrent pinnules, but the rigid fronds of *Glenopteris*, with strong axial development, are very different from the fronds of *Megalopteris*, large, and often bifurcate at the top.

Glenopteris has, in the shape and development of the frond, a very striking resemblance to the Mesozoic genera *Lomatopteris* Sch. and *Cycadopteris* Zigno. The resemblance of the large species of *Glenopteris* to *Lomotopteris* is especially close. The form and method of development of the frond in the two genera are very similar. Both have a strong, roughly striate rachis, and pinnules reduced at the base of the petiolate frond. *Lomatopteris* is described by Schimper as having its venation entirely obscured; the venation of *Glenopteris* is always indistinct, and, in *G.? lobata*, entirely concealed. The auricled base, which distinguishes most of the species of *Glenopteris* from *Lomatopteris*, is wanting in *G.? lobata*. This latter species further resembles *Lomatopteris* by a very similar lobation of the borders. The essential character separating this species from that genus is the absence of the thickened border.

Doctor White* has already suggested the possible relation of the Alethopterideæ with the Triassic genera *Lomatopteris* and *Cycadopteris*. The genus *Glenopteris* from the Permian having an evident relation to both *Protoblechnum* from the base of the Coal Measures, and to *Lomatopteris* and *Cycadopteris* from the Trias, makes such a relation much more probable. As far as it is possible to conclude from the evidence of sterile fronds, these three genera seem to have a direct genetic relation.

Glenopteris splendens, sp. nov. Plate XXXVII, fig. 1; plate XXXVIII, fig. 1; plate XL. Type 5106.

Fronds large, deeply pinnatifid, slightly curved or straight, coarse, spreading, broadly elliptical, 45 or more cm. long, with a spread of about 20 cm., thick in life, leaving a dark carbona-

*Bull. Geol. Soc. Am., vol. IV, 1893, p. 119.

ceous layer on the rock, petiolate, broadest in the middle, tapering to base and apex. Rachis strong, rigid, continuing well towards the apex of the frond, roughly marked with longitudinal striæ; in the fossil condition flat, or the original more or less cylindrical shape indicated by a depression in the stone, about one-third wider than deep, partly filled with carbonaceous matter. Petiole of the frond very strong, striate, 1 cm. wide at the base, broken off short, as if detached from an arborescent stem or possibly a larger division of the frond. Pinnules close, connate or overlapping at the base, alternate or subopposite, oblique to the main rachis, or lower ones reflexed, linear; base sessile, decurring or strongly auricled below, somewhat rounded above, borders entire, straight, and nearly parallel. Pinnules sloping very gradually from the base to the obtuse apex, varying much in size and shape according to the position on the frond; those at the middle reaching a length of 13 cm. and a width of 2 cm. at the base, strongly auricled, the auricle overlapping two-thirds of the distance to the midrib of the next pinnule below; those at the base of the frond open or reflexed, more narrow in proportion to their length, less distinctly auricled or merely connate, or even distinct; those towards the apex also reduced, broader in proportion to their length, becoming near the apex broadly oblong, oblique, with decurring base, 1 or 2 cm. long, 1 cm. or more wide. Midvein of the pinnule broad but shallow, continuing two-thirds the length of the pinnule, then gradually fading out. The center of the furrow is marked by a narrow depression, which shows in the cast of the upper side of the frond (photo pl. XL) as a fine, distinct line running through the center of the pinnule. Lateral veins indistinct, thin, almost hidden in the epidermis. They leave the midrib obliquely, curve outwards, and meet the borders almost at right angles, simple or forked once, 12 to 14 per cm. The veins of the auricles are strongly curved, often once forked. Occasionally the auricle shows a very slight constriction of the base of the pinnule, as if about to become lobed.

Three good specimens of this species have been found, but none of them showing the complete apex. On the same rock with the basal part of the frond, fig. 1, plate XXXVIII, occurs a part of a frond from near the apex, probably referable to this species, with broadly oblong pinnules, close, oblique, and grad-

ually reduced. The specimen photographed (plate XL) also shows the pinnule approaching the apex, becoming shorter and proportionally broader.

On the rachis of one specimen of this species there occurs a narrowly elongate scar, 3 mm. long and less than a half mm. wide. A similar but smaller scar occurs on the rachis of a fragment probably referable to this species. These scars are of interest, because of their seeming identity with numerous such scars occurring on or near the rachis of some of the *Tæniopterids* of the collection, which in turn at least resemble the scars on *Macrotæniopteris*, described as probable fructification by Fontaine.*

These scars will be more fully described in treating of the *Tæniopterids* of the formation.

Glenopteris simplex, sp. nov. Plate XXXVII, fig. 2; plate XXXVIII, figs. 2 and 3; plate XXXIX; plate XL. Type No. 5101.

Fronds small, 10 to 15 or more cm. long, simply pinnatifid, narrowly elliptical in outline, short petiolate, broadest in the middle, tapering to base and apex. Fronds apparently thick, leaving a thick carbonaceous layer on the rock; very variable in size; always curved from the base, often decidedly so, inequilateral in development, due to the excessive growth of the pinnules on the convex side of the frond. Pinnules alternate, decurrent at the base, joining the pinnule below by a winged projection, or by a more or less distinct auricle, rounded above the base, in general, oblique to the rachis; in the young frond the pinnules are close, oblique, ovate, or oblong; as the frond develops the pinnules become more distant, oblong, still leaving the rachis obliquely, but curved back at the apex; in the largest fronds the pinnules are 1 cm. distant, 3 to 4 cm. long, curving back decidedly at the apex, giving the frond a lax appearance. Pinnules at the middle of the frond largest, most distinctly curved. Apex very obtusely rounded. Borders entire, straight, or irregularly undulate. Pinnules at the base of the frond much reduced; lower ones, which are 1 or 2 cm. from the base, mere wing-like projections, 3 or 4 mm. long. Pinnules also reduced towards the apex, becoming ovate, odontopteroid in appearance, passing into undulations of a lanceolate, obtuse, terminal pinnule. The terminal pinnule is

* Monograph, Older Mesozoic Flora of Virginia, p. 18.

characteristic. It is large in proportion to the frond, somewhat irregular in shape, sloping slightly to an obtuse apex. In a frond 15 cm. high, the terminal pinnule is 2 cm. long. But the much larger apex (plate XXXVIII, fig. 2), apparently referable to this species, indicates that the terminal pinnule varies with the size of the frond. Midvein distinct, percurrent, running down the rachis 1 or 2 mm. before uniting with it, continuing almost to the apex. Lateral veins oblique, strong, simple or forking once, almost straight or distinctly curved, 10 or 12 per cm. at the border.. Veins strongly curved in passing from the rachis to the auricled base. The midvein of the pinnule becomes less marked in pinnules nearing the apex of the frond, lateral veins more pronounced, passing gradually into the lateral veins of the terminal pinnule.

This species, the smallest of the genus, is common, and its general form usually well preserved. The venation, however, is indistinct on most of our specimens. One frond (plate XXXVIII, fig. 3), fortunately, has the venation well preserved. The rachis, seen from the upper side, is marked by a broad, shallow groove; from below it presents a broken, striate appearance, due to the decurring midveins of the pinnules. Plate XXXIX shows three of the fronds, natural size, and almost complete. The frond fig. 1 has the apex broken and displaced to one side. With several good specimens at hand, it is possible to follow the development from the young to the full-grown frond. The pinnules, at first close, ovate, and oblique, become, by the growth of the frond, more distant, elongate, curved back at the apex, lax in appearance, reaching at last the extremely curved form seen in fig. 3, plate XXXVIII.

The specimen plate XXXIX, fig. 1, was among those collected by Mr. Sterling. The others were collected by the author.

Glenopteris lineata, sp. nov. Plate XXXVII, fig. 3; plate XXXVIII, figs. 4 and 5. Type No. 5108.

Fronds of medium size, deeply pinnatifid or pinnate, somewhat fleshy, narrowly elliptical, narrowing gradually to a long apex, petiolate at the base. Rachis strong, longitudinally striate or wrinkled, half cylindrical or flattened, broken off short at the base. Pinnules alternate, close, or more distant in the middle of the frond, rounded above the base, united by a

decurring wing to the pinnule below, situated very obliquely on the rachis, linear-lanceolate, straight, very symmetrical above the base, narrowing gradually and regularly from the base to the apex; borders straight and entire, apex rounded, or cut off wedge shaped. Pinnules reduced in passing to the apex, becoming shorter, proportionally wider, at last not more than 5 or 6 mm. long, 4 or 5 mm. wide, and triangular in shape. Midvein of the reduced pinnule still evident, continuing to the apex. Pinnules also reduced towards the base of the frond as in other species of the genus, lower pair reflexed. Midvein straight, deep, and narrow, deeply emersed, continuing quite to the apex of the pinnule, percurrent at the base; lateral veins obliterated in all the specimens yet obtained by the thick, longitudinally wrinkled substance of the frond.

The species is described from four specimens, two of them representing the apical part of the frond, but with the extreme apex of both broken; one from the base, and one from near or below the middle, a part of which is shown in fig. 5, plate XXXVIII. The upward curve of the long pinnule of this plate is due largely or entirely to a break below the center of the pinnule and the dislocation of the apex. Other pinnules above and below this one do not show the scythe shape.

Glenopteris sterlingi, sp. nov. Plate XLI; plate XLII, fig. 1. Type No. 5104.

Fronds large, deeply pinnatifid, the pinnules connected at the base by a lobate auricle, strong, rigid in appearance; elliptical, broadest in the middle, 25 or more cm. long; petiolate, thick, leaving a carbonaceous layer in which the veins are mostly hidden. Rachis strong, half-cylindrical or compressed in the cast, 1 cm. broad at the base, longitudinally striate. Pinnules close, opposite or subalternate, unsymmetrical, much enlarged above the base, sloping at first abruptly, then gradually, to a lanceolate apex, situated at right angles to the rachis, straight, or curving up slightly at the apex, scythe-shaped, 10 to 17 mm. distant, 6 to 7 cm. long in the middle of the frond, sessile at the base, connected by a lobate auricle. Borders entire, straight or irregularly undulate. Apex small, rounded. At the center of the frond the lobes between the pinnules are approximately twice as long as broad, about 9 mm. long, 4 or 5 wide, half cut off from the pinnule above by a sharp incision at the base

of the pinnule, connate with the pinnule below, or the outer part of the lobe overlapping slightly. In the pinnules approaching the base of the frond the lobes are progressively less strongly developed, entirely disappearing on the reduced basal pinnules. Main rachis of the frond brokenly and roughly striate throughout its entire length. Midvein of the pinnule moderately strong, continuing to near the apex, straight or nearly so, joining the rachis with a short downward curve. Lateral veins indistinct; those of the auricles best preserved. These leave the rachis with a slight curve, run straight and apparently simple to the border. In the first auricle (top of fig. 1, plate XLII, left side) six veins can be counted in the distance of 3 mm. On some of the pinnules of the eroded specimen (plate XLI) the lateral veins show indistinctly. They leave the midvein obliquely and curve in, passing to the borders; whether simple or forked, cannot be made out.

Two specimens of this species are found in the collection, both of which are photographed. The smaller one is well preserved and covered by a thick coaly layer, entirely obscuring the venation except in the lobes of the auricles. This specimen shows well the distinct lobe between the pinnules. The second specimen is of an eroded frond, somewhat defaced. The lobate base, however, is well shown on some of the pinnules. The species has a very different appearance from others of the genus, due to the odd shape of the pinnules and their lobate bases. The large specimen, plate XLI, has evidently the natural shape of the frond, except that the apices of the pinnules are broken and somewhat displaced. The frond is rigid, strongly curved at the base, and again less strongly curved in the opposite direction at the apex. The extreme apex is not preserved.

The first specimen of this species, that of plate XLI, was collected by Mr. Sterling.

Glenopteris? lobata, sp. nov. Plate XXXVII, fig. 4; plate XLII, fig. 2. Type No. 5110.

Fronds large, pinnate, petiolate, coriaceous. Rachis strong, flat, striate, 1½ cm. wide, broken off short at the base. Pinnæ close, alternate or subopposite, linear, sessile, and overlapping at the base, 1½ cm. apart, longest 6 cm., divided into numerous small, ovate, shallow, but distinct lobes. Basal pinnæ reduced

scarcely, or not at all lobed, lowest pair much reduced, 1½ cm. long, reflexed. Lobes more distinct on the lower side of the pinna than on the upper, true at least of those pinnæ approaching the base of the frond. First lobe on the lower side of each pinna attached to the main rachis. Midvein of the pinna broad, but shallow, marked on the upper side of the frond by a shallow furrow, continuing to near the apex, curved down at its union with the rachis. Lateral veins entirely obscured by the coriaceous frond.

The propriety of including this species in the genus *Glenopteris* is extremely doubtful. With the single incomplete specimen at hand, it is difficult to decide its true generic relation. In general disposition the frond is much like that of other large species of *Glenopteris*, a frond having a strong striate rachis with pinnules reduced at the base. The negative character of obscured venation may not be of especial value, since the venation of every species of the genus is more or less obscured, and additional specimens, when found, may have the venation preserved. The pinnæ, however, are very different. They can hardly be said to be auricled. They are rather sessile by the entire base, the borders lobate, the first lobe on the lower side attached to the rachis. But as observed in other species of the genus, the pinnæ of the middle of the frond may prove to be more distinctly auricled. The first large pinna at the base of the frond has only a single lobe on the lower side; the two following are distinctly lobed on the lower side, merely undulate, or slightly lobed, on the upper; the next two above these are broken; the third, the large pinna at the top of the specimen, is as plainly lobed on the upper as on the under side.

This species, as noted in the discussion of the genus, approaches very closely to *Lomatopteris* Sch. As in that genus, the veins are obscured, fronds thick, petiolate, rachis strong and striate, pinnæ lobed. The absence of a thickened border is the essential character excluding this species from Schimper's genus.

Lomatopteris burgondiaca Sap., from the Jurassic, should be compared as a species closely related in its form and development.

Doctor White has very kindly looked over the photographs illustrating this genus, and calls attention to the close resemblance of some of its species, especially *Glenopteris? lobata* to

Lomatopteris jurensis Sch., as that species is figured by Saporta, Plantes jurassiques, vol. I, p. 405, pl. 55, figs. 1–4, or *Lomatopteris cirinica* Sap., l. c., p. 409, pl. 52, figs. 1, 2. He also mentions *Cycadopteris* as developed in the Triassic as deserving comparison. Judging from the photograph alone, Doctor White is inclined to think *G. sterlingi* close to *G. splendens*, and suggests the possible occurrence of intermediate forms. The peculiar shape of the pinnules of the former species, mentioned in the description—pinnules enlarged above the base, then sloping at first abruptly, afterward very gradually, to a slender apex, the auricle cut off from the pinnule by a distinct lobe—seems to be a character constant for this species and separating it from the other. No intermediate forms have yet been found justifying a closer comparison between the two species.



A RECONNAISSANCE IN THE BLUE VALLEY PERMIAN.

BY J. W. BEEDE.

With Plate XLIII.

THIS paper has to do largely with the lower Permian and the upper portion of the Coal Measures, as they are represented in Kansas north of the Kansas river and in southern Nebraska. The sections given here are selected near the railroads, so as to be of easy access for comparison to any one wishing to study them.

The Blue Valley & Northern railroad runs along the Big Blue river from Manhattan, in the upper Wabaunsee formation, to the upper Chase formation, near Beatrice, Neb. At Stockdale, and north to Cleburne, a most excellent idea of flint-hills topography may be obtained from the railroad. The little town of Garrison, on the east side of the river, is located at the foot of a bluff more than 200 feet high capped by the Florence limestone. Randolph is located in a typical Permian valley, with steep bluffs on either side; Cleburne is in the mouth of a typical Permian gulch. By taking the wagon road from there to the northwest up the gulch, an excellent idea of the pleasures of driving in the flint hills may be obtained.

For the study of the upper Permian, good exposures may be found from Waterville to Barnes and Greenleaf, on the Central Branch (Mo. Pac.), or from Marysville to Hanover, on the Grand Island. On the latter road, the best places to study the strata are a few miles southeast of Hanover, in the large hills, some of which are 100 feet high, with all the strata exposed in the road. The accompanying map gives an idea of the approximate distribution of the formations.

WABAUNSEE FORMATION.

In volume 5, page 119 *et seq.* of the Kansas City Review of Science and Industry, 1881, Professor Broadhead published some notes on the geology of the Central Branch railroad, in which he discusses, among other things, some sections within

the area discussed in this paper. In discussing the section at Frankfort, he says:

"At Frankfort the hills extend up probably 150 feet above the Vermillion valley, and seemed formed in the lower portion chiefly of shales for over fifty feet, with probably one limestone suitable for building near the lower part. These beds I refer to the middle Permian, the lower probably cropping out eastwardly.

"Toward the top of the hill about four feet of good building stone is quarried. In the quarry is an ash-gray magnesian limestone, weathering cream color, and works out very freely. The quarry rock is of a very porous texture, caused by the decomposing and loss of numerous *Fusulinæ*: it also contains many chert concretions, which does not seriously interfere with its use as a building stone.

"Five miles west the same beds appear in the bluffs, but lower down, at Barrett's station.

"Still farther, several miles, at Bigelow station, these beds are well exposed, and the stripping exposed to view better layers of stone. A good deal of quarrying has been done here, and preparations are making for much more.

"In the beds I observed the following fossils: *Productus semireticulatus*, with *Fusulinæ* very abundant, but other fossils very rare."

The lower portion of the section at Frankfort, referred by Broadhead to the middle Permian, is the upper part of the Wabaunsee formation of the Coal Measures, while the "ash-gray magnesian limestone" is the Cottonwood Falls limestone. That the abundant fauna of *Derbya*, *Seminula* and *Chonetes* should have been overlooked seems queer when the shale above the stone he describes unmistakably at Barrett and Bigelow is almost composed of these shells.

The Blue river cuts through the Cottonwood formation at Manhattan and well into the top of the Wabaunsee formation. The geology of this locality has been amply described by Professor Prosser,* and only one section farther north will be given for comparison with it. The section is located on the south fork of the Black Vermillion, east of Barrett station. The section rises from the bed of the creek to the top of the hill, a half a mile to the westward.

South Fork Section.

	Stratum. ft. in.	Total. ft. in.
22. Soil at the top of the hill	5—0	183—0
21. Cottonwood limestone, best exposed in quarry south of road,	3+	177—6
20. Covered slope	10—0	174—6
19. Gray limestone, uneven texture, 2 to	4—0	164—6
18. Olive and reddish argillaceous shale in the upper part, the lower part covered	23—0	160—6
17. Yellowish to gray limestone	5—0	137—6
16. Covered slope, apparently composed of olive indurated shale,	5—0	132—6
15. About two feet of yellowish-gray limestone, not very fossiliferous	2—0	127—6

*Bull. Geol. Soc. Amer., VI, p. 32 *et seq.*

South Fork Section.	Stratum. ft. in.	Total. ft. in.
14. Covered slope	5—0	125—6
13. Apparently layers of grayish limestone, on top of first little hill	8—0	120—6
12. Indurated, yellowish, calcareous shales, forming yellowish and olive limestones, three layers about five feet apart. *Productus nebrascensis*, *Ambocœlia planoconvexa*, and other imperfectly preserved fossils	15—0	112—6
11. Shaly limestone, upper part of which is a massive yellowish limestone, weathering to a dirty gray. It contains *Fusulina* and many small fragments of fossils. The lower and more shaly portion is not very fossiliferous	7—0	97—6
10. Yellowish shale	8—0	90—6
9. Brown, porous, fossiliferous limestone containing abundant *Pleurophorus subcuneatus*	0—10	82—6
8. Yellow and olive indurated shales, very fossiliferous in the lower portion	25—0	81—8
7. Gray argillaceous limestone	0—8	56—8
6. Shales, not well exposed, mostly olive or yellowish	15—0	56—0
5. Hard, gray, fossiliferous limestone, weathering brown, 8 inches to	1—0	41—0
4. Olive, clayey or slightly sandy shales, about	5—0	40—0
3. Covered slope, from creek bank to section in road	33—0	35—0
2. Gray, clayey limestone, in creek bed	0—6	2—0
1. Variegated arenaceous shale, in creek bed	1—6	1—6

Nos. 1 and 2 may have sunken from their original position, though they appear undisturbed.

COTTONWOOD FORMATION.

The Cottonwood Falls limestone together with the superjacent shales form the uppermost portion of the Coal Measures. In this region the limestone is well developed, and quarried wherever it outcrops. It has the characteristic appearance here, being a whitish or buff-gray limestone, appearing white from a distance, filled, in the upper portion, with *Fusulina secalica* or the cavities from which they have been dissolved. Chert concretions are often prominent in the upper portion. The overlying shale, however, seems to be thinner here than to the southward across the Kansas river. They average a trifle over two feet thick in this region, being scarcely two feet in thickness at the Hawk quarry, at Beattie. The chief quarries are located at Barrett, Bigelow, Florena, Manhattan, and Beattie. At Frankfort, the quarries are located on the tops of the hills southeast of the city. There is very little soil above the limestone, and it is split into large blocks of flagging; the lower portion of the upper layer is used for this purpose and the rest is used for building purposes.

As early as 1858 Mr. Henry Englemann noted this rock,

probably in the vicinity of Frankfort or Barrett. After referring to the rocks near Seneca and westward, he says: "On the Vermillion, some miles south of the road, a whitish magnesian limestone is quarried, remarkable on account of the large number of small cavities which it presents, all caused by the weathering out of *Fusulina cylindrica.* A stratum very much like this has been observed near the mouth of the Blue river, and No. 22 of Messrs. Meek and Hayden's section presents the same character."* There can be but little doubt that the stone referred to at the mouth of the Big Blue and that mentioned here were the Cottonwood limestone. Bed 24 of Meek and Hayden is the Cottonwood, according to Prosser.†

Prof. E. B. Knerr, in discussing the Frankfort section, says: "South of Frankfort the bluffs rise to a height of 160 feet above the railroad, and have the Cottonwood Falls limestone on their summits, about four feet thick. Beneath these to the base of the bluff is a succession of shales fifteen to thirty feet thick, alternating with ledges of limestone eight to five feet thick. The ledges of limestone terrace the bluffs, about six terraces being especially prominent."‡

Bigelow Section. §	Stratum. ft. in.	Total. ft. in.
4. Impure limestone	2—9	9—1
3. Fossiliferous shales	2—7	6—4
2. Cottonwood Falls limestone, upper part	2—3	3—9
1. Lower stratum of the same	1—6	1—6

The limestone at this locality is unusually white, and works much better than that from the region of Beattie or the large Florena quarry. A fish tooth and a specimen of a large *Orbiculoidea* were taken from the shales at this place. A section of the Mead quarry, at Barrett, is given below for comparison. The section is taken at the north end of the quarry.

Mead Quarry Section. ‖	Stratum. ft. in.	Total. ft. in.
4. Shaly, argillaceous limestone	1—2	9—7
3. Yellowish fossiliferous shales	3—8	8—5
2. Nearly white limestone (Cottonwood), three layers	4—9	4—9
1. Slope covered, about fifty feet.		

No. 3 of this section (the Cottonwood shales) is richer in fossils here than at any other locality north of the Kansas river. No. 4

* Simpson, Expl. Gt. Basin Utah, 1859, p. 254.
† Loc. cit., p. 37.
‡ Univ. Geöl. Surv. Kans., II, p. 143.
§ Sunflower quarry, central part (the limestone shows thicker farther south).
‖ Between Barrétt and Bigelow.

is considerably thicker at some localities than at others. At the Hawk quarry, at Beattie, it is seven feet in thickness. For comparison, the Hawk quarry section is given below:

Hawk Quarry (at Beattie).

	Stratum. ft. in.	Total. ft. in.
7. Hard shales and argillaceous limestones	7—0	19+
6. Limestone	1—8	12—2
5. Limestone	1—6	10—6
4. Very hard fossiliferous shale	2—0	9—0
3. Limestone with abundant *Fusulina* and chert nodules	2—8	7—0
2. Limestone with thin layers of chert concretions	2—0	4—4
1. Gray limestone with blue streak through center	2—4	2—4

Nos. 1 to 3 are the Cottonwood Falls limestone. The difference in the appearance of the shale is probably due to the greater protection which it had in this quarry, and suggests that it might be difficult to correlate sections in this region by well records, as the argillaceous limestones and calcareous shales would present about the same appearance to the average workman.

The above sections give an ample idea of the Cottonwood formation in this region. The Florena section would be a repetition of the others. On the whole, it presents about the same appearance as south of the Kansas river. The stone has the same color and texture and thickness and is extensively quarried in many places. The overlying shales seem to be a little thinner here than south of the Kansas river, but present the same faunal characteristics, with their millions of *Chonetes granulifer* and many *Derbya* and *Seminula argentea*. This characteristic is quite as prominent a feature as the texture and color of the limestone below.

NEOSHO FORMATION.

This formation, the base of the Permian, is a rather narrow band geographically, and follows closely the underlying Cottonwood formation, as it is not much more than 100 feet in thickness, and the escarpments formed by the Strong flint and Cottonwood limestone are generally rather close to each other. Professor Knerr gives a section in this formation near Bigelow which would show it to be ninety-eight feet in thickness. His section of the bluffs is as follows: *

"A little south of Bigelow the Permian first becomes conspicuous in the bluffs called Twin Mounds. Here the Cottonwood Falls rock is thirty feet above the railroad, and is six feet thick.

* Loc. cit.

"The following section is observed reaching from the top of the mound to this Cottonwood Falls rock:

"1. Ten feet of limestone, with flint nodules very abundant in the upper portion.
"2. Fifty feet of buff shales and thin limestones.
"3. Thirty inches of porous limestone, with eight to ten inches of prismatic blue flint overlying it.
"4. About thirty feet of shales and thin limestones.
"5. Thirty inches of hard prismatic limestone.
"6. Two feet and ten inches of a compact limestone.
"7. A three-foot bed of calcareous shales very full of fossils.

"The upper strata (1) are very characteristic and persistent. They were traced north along the Blue river to the Nebraska line and west to Washington county. They occasion the flat-topped bluffs so conspicuous on either side of the Blue river from Bigelow to Waterville. The flint nodules in the upper stratum are quite like agate in concentric structure. The limestone in which they are embedded is quite soft, and weathers easily, leaving the nodules exposed and protruding."

The Strong flint passes beneath the Big Blue river about three miles south of Marysville, and the Florence flint passes on north into Nebraska. According to Knerr, the flint on top of the hills at Waterville, Blue Rapids, Marysville, Irving and at Twin Mounds is all the same. From his section, it is difficult to ascertain whether the Strong flint or the Florence flint is meant, because both flints occur in the region. The bluffs at Irving are certainly capped by the Strong flint, as are also those north of Blue Rapids, while the bluffs at Waterville, Marysville and northward contain the Florence flint and limestone.

The following section, on the north side of the Dennis farm, just east of Bigelow, passing up the hill going east, gives an excellent idea of the Neosho formation in the north Kansas Permian. The section is exposed in the road and every inch of the strata is visible. The section is given in minute detail, to give an idea of the general nature of the formation here. While the minute details vary in going a short distance, yet the general appearance does not vary greatly.

Dennis Section, east of Bigelow. *	Stratum. ft. in.	Total. ft. in.
21. Gray limestone near the top of the hill	?	
20. Shales, uppermost part quite calcareous	15—0	86—4
19. Gray limestone	1—2	71—4
18. Green and red shales	12—0	70—2
17. Gray, impure limestone with *Pseudomonotis*	2—0	58—2
16. Dark red and yellow shales	10—0	56—2
15. Gray limestone in four thin layers	1—8	46—2

* North side section 12, Bigelow township.

Dennis Section, east of Bigelow.	Stratum. ft. in.	Total. ft. in.
14. Olive shales	3—6	44—6
13. Greenish-gray limestone, many small fragments of fossils, shaly in the middle	1—0	41—0
12. Yellowish arenaceous shales	1—6	40—0
11. Light gray, fine-grained sandstone	0—6	38—6
10. Green shales	10—0	38—0
9. Three-inch layer of clayey limestone	0—3	28—0
8. Olive to yellowish, mostly indurated shales, soft above, with small calcite nodules	10—0	27—9
7. Mud-cracked limestone, a continuation of the stratum below,	5—0	17—9
6. Yellowish-gray, clayey limestone or indurated calcareous shale	0—6	12—9
5. Yellow shale, fossiliferous (*Derbya crassa*)	1—0	12—3
4. Shaly argillaceous limestone, massive above, grading into stratum below	1—6	11—3
3. Yellowish fossiliferous shale, about	4—0	9—9
2. Cottonwood limestone layers, aggregating	5—9	5—9
1. Covered slope to the little creek below, about thirty-nine feet.		

Some distance above this section the Strong flint sets in. It will be noticed that there is no limestone with a layer of flint above in the above section, as given by Professor Knerr in the section farther west, though the section rises considerably higher above the Cottonwood limestone. However, there is such a layer at Blue Rapids, in the creek west of the Great Western Plaster Company's mill, on the road running north.

Prof. G. C. Broadhead (loc. cit.) observed a section near Blue Rapids which includes at least a part of the Neosho formation and part of the Chase. He states that it is a general section. It probably extends back into the hills a considerable distance. The section is as follows:

"The following is about a general section of the rocks seen at Blue Rapids, ten miles further west [from Bigelow], and includes beds still above those just named, and also Permian:

"1. On hilltop a bed of limestone near summit.

"2. One hundred feet probably all shale; some chert on slopes.

"3. Four feet of magnesian limestone, in layers of four to twelve inches.

"4. Fifteen feet shales with small geodes.

"5. Four feet limestone in sixteen-inch layers; color whitish drab, with blue chert between the layers. This limestone is much used in building in Blue Rapids, and affords a handsome building rock.

"6. Thirty feet shales.

"7. One and one-half feet good bed of building stone, coarsely cellular; also extensively used.

"8. Thirty feet shales, red in lower part.

"9. Four feet limestone.

"10. Four feet nodular shales.

"On river bluffs above, the red shales at several places carry lenticular forms of gypsum, often snowy, and in quantity sufficient to utilize. There is a mill at Blue Rapids constantly engaged in grinding it up for plaster. Some of these beds are nine feet thick. A strange feature was observed in some of the lower beds of these rocks. In five feet thickness, observed four beds of rock of nearly uniform thickness, sixteen to twenty-five inches, each one with a layer of blue chert on top."

He does not state which stratum of the above section the last two sentences of the quotation refer to, but from the reading they refer to No. 5, which is the Strong flint. He notes the fossils collected in this section in the following manner:

"*Fusulina cylindrica* abounds; also found *Athyris subtilita*, *Productus semireticulatus*, *Chonetes granulifer*, *Eumicrotis hawnii*, *Hemipronites crenistria*."

Dr. G. P. Grimsley also gives a somewhat generalized section of the rocks as they appear in the bluff at the Great Western plaster mill.*

This section will be seen to compare in a rough way with Broadhead's section, the difference probably being due to the sections being taken at different localities. The top of Grimsley's section corresponds to No. 5 of the Broadhead section.

This formation extends up the Blue river nearly to Marysville, and west to Waterville, and on Wildcat creek west of Manhattan, a little beyond Keats. It extends north into Nebraska, in the vicinity of Summerfield, and is quite prominent in Pottawatomie county.

THE CHASE FORMATION.

THE STRONG FLINT.—The geography of this stratum, which forms the base of the Chase formation, is the same as that of the previous formation. It is quite prominent at Keats, Irving, and Blue Rapids. At many other points it is of less marked importance, though always a well-marked terrace or escarpment. The stratum can perhaps be best studied at Waterville and Garrison, where the following sections were taken. The one at Waterville is from the west side of the road, north of the Waterville bridge over the Little Blue river.

	Stratum. ft. in.	Total. ft. in.
5. Three layers of flint alternating with limestone, some of the layers of flint nearly a foot thick in places	4—0	12—0
4. Limestone, from 1 foot to	4—0	8—0
3. Calcareous shale	1—0	4—0
2. Massive limestone, with layer of flint in the top	3—0	3—0
1. Yellowish shales and covered slope to river-bed.		

* Univ. Geol. Surv. Kans., V, p. 54.

Section on south side of creek, a quarter of a mile west of the junction, at Garrison: *

	Stratum. ft. in.	Total. ft. in.
8. Limestone and flint	2—0	15— 0
7. Flint	0—4	12—10
6. Hard yellowish limestone, weathering to light gray	1—4	12— 6
5. Limestone, with four inches of flint above	1—1	11— 2
4. Clay, parting with warty limestone above	1—0	10— 1
3. Limestone, half flint through the middle	1—1	9— 1
2. Blue shales	2—0	8— 0
1. Limestone	6—0	6— 0
Covered from bottom of section to creek bed.		

A portion of the section at Waterville was covered, and it is quite possible that a portion of both top and bottom of the section was not exposed. Above that section are many feet of clay deposit of recent age, resembling not a little the reddish drift clays of the eastern part of the state. There are also good exposures of the Strong flint east of Irving, where it forms the tops of the steep bluffs on the east side of the Blue river. East of Blue Rapids this flint is exposed in the heads of the little creeks.

The outcrop from the Strong flint to the base of the Florence flint is almost always covered. I know of no locality where the entire strata are exposed. For some distance above the Strong flint are shales and thin limestones, and for about forty feet below the Florence flint are blue, green and olive shales, with a two-foot stratum of limestone. These shales are best exposed at the base of the following section, west of Garrison.

FLORENCE FLINT AND LIMESTONE.—These are the most marked and striking deposits in the Blue Valley region. They are always prominent, adding more than any other single group of rocks to the ruggedness of the flint hills. Its forty or fifty feet of flint and limestones underlaid with soft shales make its outcroppings precipitous wherever they occur.

Prof. W. C. Knight † has correctly correlated these rocks with those of Wymore, Neb. They are prominent in the bluffs of the Blue river from Wymore to Stockdale, Kan., being interrupted at Blue Rapids by a local fold in the strata. At Oketo it is a little under 1250 feet A. T., ‡ and at Garrison it is about 1200 feet

* Since comparing this section with others of the Florence flint, it seems possible that it may be a dislodged portion of a cliff of the Florence flint, though it appears to be in its natural position.

† Jour. Geol., VIII, p. 368 (1900).

‡ U. S. Topographic Sheets.

A. T. Garrison is considerably west of Oketo, this showing a slightly northerly dip of the strata, beside the usual dip of twenty feet or more to the mile to the westward. Blue Rapids is about due north of Garrison and four miles west of Oketo. According to these data and the elevation of the bluffs at the Great Western mill, the Florence flint and limestone should occupy a position there as low or even lower than that occupied by the Strong flint, showing the anticline at this place to be seventy-five or eighty feet.

A similar fold occurs with its crest at Wymore, Neb. According to the direction of the river and the dip of the strata, the Florence flint should be either in or beneath the bed of the river at Wymore, while as a matter of fact it is high above it; the bluffs formed by it rising 90 or 100 feet above the water. This is clearly brought out by Knight's determination of the dip of the strata in this region, concerning which he says: * "It was found that these rocks had a southern dip of five feet to the mile."

The study of the Nebraska portion is left largely to the Nebraska geologists, who, I was informed, made a very careful survey of the region there the previous summer. Professor Knight's paper brings out the salient features very clearly.

The best section of this flint and limestone north of the Kansas river is near the depot at Oketo. Here almost the entire section is shown in a single vertical exposure. This section, together with the quarries, gives an excellent idea of the appearance of this limestone and flint in the Nebraska and northern Kansas area. It differs somewhat from the same rocks farther south, as will be noticed in the following sections. There is also some difference in appearance in the quarry sections and the weathered exposures.

Oketo Section Florence Flint and Limestone, near the depot.

	Stratum. ft. in.	Total. ft. in.
13. Oolite, same as in the Moore quarry	+	
12. Light-colored, calcareous, indurated shale	2— 0	56—11
11. Yellowish, irregular, perhaps siliceous limestone	2— 0	54—11
10. Massive limestone, similar to No. 9, but more yellow on weathering and is fossiliferous	4— 5	51—11
9. Massive limestone, cellular, or with little geodes, olive buff, weathering to yellowish gray	5— 0	47— 6
8. Yellowish shale	5— 0	42— 6

* Loc. cit., p. 369.

Oketo Section Florence Flint and Limestone, near the depot.

		Stratum. ft. in.	Total. ft. in.
7.	Drab, clayey, blocky limestone	3— 6	37— 6
6.	Bluish, shaly limestone	7— 0	34— 0
5.	Third layer of limestone, containing flint	4— 0	27— 0
4.	Limestone with great quantities of dark flint	6— 6	23— 0
3.	Limestone with four prominent layers of dark flint	3— 8	16— 6
2.	Blue, argillaceous, shaly limestone	2—10	12—10
1.	Red and variously colored shales or marls	10— 0	10— 0

Add to this the rocks exposed east of town, and we have the following section: Oolite, two feet six inches: shaly rock and covered slope, ten feet, with a two-foot "foundation" rock. This makes the complete section of the Florence limestone and flint as it appears in the north Kansas-Nebraska region. The oolite seems to be confined to the northern part of the region. West and south of Marysville, near the head of Walnut creek, north of Waterville, the heavier limestone forming the bluffs there shows some oolitic structure, which is the farthest south that it was observed. At Marysville, the upper very fossiliferous rock, in the pasture north of the road running east, shows brownish oolite in places.

A fairly good exposure of the Florence flint and limestone is shown in the hill a mile and a half north and a little east of the Waterville bridge, in the road running up the hill. There are more than thirty-five feet of them exposed here; the lower twelve feet are flints and limestone, above which are shaly limestones to the main ledge, of which three feet are shown. Above this are red, green and olive shales, with a few thin shaly limestones for about thirty-five feet, over which lies an ill-exposed limestone.

FLORENCE FLINT WEST OF GARRISON.

About a mile west of Garrison is a very high bluff facing the east, on the south side of the railroad. There is not a continuous section at this place; but, by beginning at the northern part of the exposure in the creek and working to the base of the flint, and then going south where the bluff becomes steeper, and continuing from the base of the flint to the top of the bluff, the following section may be seen:

Garrison Section.

		Stratum. ft. in.	Total. ft. in.
12.	Thin layer or two of limestone	2+	
11.	Massive hard, gray limestone, weathering very rough	4—8	88—8
10.	Yellow shale and covered slope	15—0	84—0

Garrison Section.	Stratum. ft. in.	Total ft. in.
9. Flint and limestone	3—3	69—0
8. Yellow fossiliferous shale	2—6	65—9
7. Limestone and flint	2—0	63—3
6. Thin layer of yellow shale	1—0	61—3
5. Alternating layers of flint and limestone	14—0	60—3
4. Red, yellowish and greenish shales	23—0	46—3
3. Shaly limestone	1—3	23—3
2. Grayish limestone	2—0	22—0
1. Covered slope from creek bed, about	20—0	20—0

MARION LIMESTONE.

The greater part of the time was spent in studying the Florence flint down to the Wabaunsee formation and the collection of fossils for comparison with those of the Coal Measures. For this reason, but little time was given to the higher strata.

The Marion limestone is found in the higher of the elevations, near Barnes. It is much less conspicuous than is the Florence flint and limestone of the region. Above this limestone the rough country of the flint hills disappears, and we have a level prairie extending westward to the Cretaceous, which appears west of Greenleaf. This limestone and the overlying Marion formation are found east of the Little Blue on the higher land, and on to the southward, to the vicinity of Riley Center and Fort Riley. It may appear also in the vicinity of Fostoria, in Pottawatomie county.

The characteristic concretions of this limestone are probably present in this area, though probably less conspicuous than in the southern area.

SOUTH AMERICAN MUSCIDÆ IN THE COLLECTION OF S. W. WILLISTON.

BY GARY DE N. HOUGH.

(With Plates XLIV, XLV.)

THE following notes and descriptions are the results of the study of material submitted to me for examination by Dr. S. W. Williston, of the University of Kansas. The material was collected by Mr. H. H. Smith, about fifteen years ago, mostly in Brazil.

CALLIPHORINÆ.

Lucilia cæsar L.

Lucilia parensis Macq.
Lucilia princeps Rond.

A number of specimens of this cosmopolitan species are contained in the collection. Some of them agree with Macquart's description of *L. parensis*, and others with Rondani's of *L. princeps*. I can find, however, no structural differences whatever between these and the typical *L. cæsar*, to which I therefore refer them.

Wiedemann, Macquart, Desvoidy, Rondani, Walker, and Bigot, who have described nearly all the South American Calliphorinæ of our catalogues, rarely mention any structural differences, but rely wholly on color for separating the species. There can therefore be little doubt that most of the published names are synonyms and will ultimately be dropped. It is very important to recognize the fact that color is of very little importance for distinguishing species in the genera *Lucilia*, *Phormia*, and *Chrysomyia*, because all the species are colored about the same, and in each species the individual variation is great. Metallic purple, green, blue, bronze and copper color are the prevailing tints, and occur in nearly every species, even on different parts (or with varying incidence of light) of the same individual.

Chrysomyia segmentaria Fabr.
Musca segmentaria Fabr., Wied.
Chrysomyia hyacinthina R. D.
Lucilia hyacinthina Macq.
Lucilia nubipennis Rond.
Mya semidiaphana Rond.

Wiedemann expressly states in his preface that he had access to the collection of Fabricius and to the Lund collection, from which Fabricius described many species. Wiedemann's positive assertion, therefore, that his *M. segmentaria* is that of Fabricius and that Fabricius made a mistake in his description must be accepted. Rondani suggested the name *Lucilia nubipennis* in place of *L. segmentaria* Wied., which he considered different on account of the difference in the descriptions above referred to; but, since *segmentaria* Wied. is the same as *segmentaria* Fabr., the name suggested by Rondani must be dropped.

Desvoidy's description of *C. hyacinthina* agrees with specimens of *C. segmentaria* before me. Desvoidy's name must therefore be given up.

Macquart thought he had Desvoidy's species, but referred it to *Lucilia*. Rondani's description of *Mya semidiaphana* agrees with specimens before me, except that he says the halteres are white. Some of my specimens have pale yellow halteres, and such a color difference is of no specific value.

Eight males and three females; Chapada; November or undated.

There is very little to add to Wiedemann's description of the color of this species. He says that the thorax is yellow on the four corners and that the pleuræ are ferruginous yellow, though if looked at in a certain direction they have a green-gold luster. This is true of but one of my specimens. All the rest have these parts of the same color as the dorsum of the thorax. The tibiæ and tarsi may be almost as yellow as the femora.

For about the middle two-fourths of the front the eyes of the male are almost in contact, the frontal vitta having entirely disappeared and the geno-vertical plates being reduced almost to nothing. Transfrontal bristles are present only on that part of the front which is ventrad this narrow portion. The great ocellar bristles are small and parallel. The lesser ocellars are hardly visible. The usual vertical bristles are absent, except a small inner vertical.

The head of the female is 3.0 mm. wide in one of the specimens and 3.1 in the others, the front being in the former 0.8 mm. and in the latter 0.9 in width. The vitta is not pollinose. The geno-vertical plates are yellowish gray pollinose on their ventral half or two-thirds, polished on the dorsal half or third. The transfrontal bristles are ten or twelve in number and are rather stout (as are all the bristles of the head). Laterad the transfrontals are two proclinate orbitals in the usual position and ventrad these a number of tiny bristlets. The great ocellar bristles are normal in direction but not large. There are several pairs of lesser ocellars, one of which, situated just caudad the posterior ocelli, is about half as large as the great ocellar, while the postvertical is very small and delicate. Laterad the ocelli is one ascending frontal. The inner and outer vertical bristles are of good size; the occipito-central is present, the occipito-lateral absent.

The cilia of the posterior orbit form a single normal row in both sexes. The dorso-ventral diameter of the bucca is one-fourth that of the head.

The chætotaxy of the thorax is shown in figure 1. There is some variation in the dorso-central bristles. We always find three caudad the transverse suture, as represented in the diagram. The most caudad is the largest, and the third is the smallest of these three. Cephalad these we find either one or two more, so small as to be distinguished with some difficulty from the microchætæ. If but one is present, it is larger than either of the two, if two are present. Cephalad the transverse suture there are always two of small size and sometimes a third, which may be midway between the other two or nearer the more cephalad of them. I have indicated in the diagram that there are two small bristles on the disc of the scutellum. In small specimens there may be but one, and in large specimens one of the two may be marginal.

In the Sarcophaginæ, Calliphorinæ, Muscinæ, and Cœnosiinæ, the bristles of the scutellum are as follows: (1) Jugal, a small bristle inserted on the caudal end of the little jugum, which unites the scutellum near its cephalo-lateral angle with the mesonotum; (2) postjugal, the large bristle just caudad the jugal, inserted on or very near the margin of the scutellum; (3) apical, the large bristle inserted very near the apex of the

scutellum on or close to the margin, and very frequently decussating with its fellow of the opposite side; (4) marginal, the macrochætæ inserted on the margin between the postjugal and the apical; (5) discal, always small and often absent, inserted on the dorsal surface of the scutellum, but not on the margin. Of these, the jugal and postjugal are nearly constant, the apical is always present, the marginal is less common, and the discal very often absent. It is noteworthy that, among the Calliphorinæ, the genera *Calliphora*, *Protocalliphora*, *Phormia* and *Lucilia* all have two marginal scutellar bristles, while *Chrysomyia* has either one or none.

Bristles of legs.—Anterior femora: Normal; all are rather delicate, but stouter toward the apex. Anterior tibiæ: On lateral surface one bristle at about the junction of the middle and apical thirds; on the mesal surface there are usually no prominent bristles, but in one male four, and in each of the two females two, of the extensor row of small bristles are of sufficient size to catch the eye. Middle femora: On the extensor surface there is only the usual transverse apical group; the usual row of the flexor border is made up of rather scattered and delicate bristles; the usual median row of the anterior surface is represented by but one bristle, situated at the middle of the segment. Middle tibiæ: The usual large bristle of the flexor surface is not far from the junction of the middle and apical thirds; on the anterior surface there is one bristle nearly on the same level with that of the flexor surface; on the posterior surface there are three, two on the flexor half of the surface (situated at the junction of the basal and middle, and middle and apical thirds, respectively), and one on the extensor half at a level a little basad the more apical of the other two. Hind femora: Normal, but rather delicate. Hind tibiæ: Near flexor border of the lateral surface two or three small, slender bristles, and near the extensor border two or three (in one male, four); on the mesal surface only two, both near the extensor border; on the extensor border the usual preapical.

Wing is shown in figure 2. The third longitudinal vein has spines at the base only.

Brauer and Bergenstamm founded the genus *Paralucilia* on *Calliphora fulvipes* Macq., and give as the only character for separating it from *Lucilia* that the third longitudinal vein is

spinose at the base only. The species was believed by Lynch to be identical with *Chrysomyia macellaria* Fabr., and with this opinion I concur. The species belongs to the genus *Chrysomyia*, and the name *Paralucilia* should be dropped. The extent of the spines at the base of the third vein varies in different species, and may be as much as half way to the small cross-vein.

Chrysomyia purpuræ.

Musca purpuræ Walk., Dipt. Saund., p. 337.

I recognize, of course, that it is rather hazardous to identify a species as one of Walker's, but if one can interpret his words, "a luteous scapula on each side of the fore breast," as meaning that the prostigma is yellow, then I may feel quite confident of the determination.

One male and four females; Chapada; no dates.

Length, 5 to 8 mm. Dorso-ventral diameter of bucca one-fifth that of head.

As in the preceding species, the eyes of the male are almost in contact over the middle two-fourths of the front, and the transfrontals are limited to that part of the front ventrad the narrow portion.

The width of the front of the female is to the width of the head as 1:3.5. The bristles of the head in both sexes are as in *segmentaria*, but rather more delicate, except that on the geno-vertical plate laterad the transfrontals the tiny bristlets do not end dorsad at the more ventral of the orbitals, but continue dorsad to the vertex. The whole vitta and the whole geno-vertical plate are thickly yellowish-gray pollinose.

The thorax is much more pollinose than in *segmentaria*, even the scutellum, meso-pleura and sterno-pleura appearing white pollinose if viewed by very oblique light. The hairs of the meso- and sterno-pleuræ are black; in *segmentaria* they are yellow. The bristles of the thorax are shown in figure 3. Only the two most caudad of the dorso-centrals are at all prominent. There is no lateral posthumeral. In every specimen there is one large marginal scutellar and one fair-sized discal scutellar. Squamulæ pale yellowish brown to white. The legs are as in *segmentaria*. The wing is shown in figure 4. The spines of the third longitudinal extend about one-third the distance to small cross-vein. Bristles of legs as in *segmentaria*.

Chrysomyia desvoidyi nov. sp.

Four males and two females; Chapada; no date.

Length, 8 to 9 mm. Metallic purple, with three faint stripes on thorax; buccæ, antennæ and palpi yellow; legs brown; wings hyaline, with blackish base; first segment of abdomen and caudal borders of second and third blackish; sterno-pleural bristles, 2 : 1; humerals, four; dorso-ventral diameter of bucca one-fourth that of head.

The eyes of the male are almost in contact for about the middle two-fourths of the front, 0.5 mm. At this narrow part there is a linear vitta and the geno-vertical plates are reduced almost to nothing. Ventrad this portion the geno-vertical plates are much narrower than in the female, yellowish pollinose, and bear about ten transfrontal bristles. Dorsad the narrow part there are no transfrontals, and the whole front is black. The great ocellar bristles are parallel, proclinate, and small. The lesser ocellars, including the postvertical pair, are mere tiny hairs. The inner vertical is of fair size, the outer vertical absent, the occipito-central present. Cilia of posterior orbit in one complete row, black, not large. Occiput covered with yellow hair, as far as I can see it. The posterior orbit is yellow pollinose; it narrows dorsad and vanishes about 0.5 mm. from the vertex.

The front of the female is one-fourth as wide as the head. The vitta is black, more or less reddish toward the antennæ. The geno-vertical plate is about half as broad as the vitta, its ventral half or two-thirds yellow pollinose, the pollen becoming thinner as we pass dorsad until it wholly disappears, the dorsal third being polished black. This dorsal third is thickly beset with very minute black hairs; passing ventrad these hairs become more scattered, and on the ventral third are distinctly in two rows and of a yellow color.

The transfrontals are about ten, not large, and end a little ventrad the anterior ocellus. There is one ascending frontal a trifle caudad the posterior ocelli. Laterad the transfrontals there are two small, equal, proclinate orbitals. The greater ocellars are normal; there are about six pairs of lesser ocellars, and the exceedingly small postvertical is evidently a member of the lesser ocellar group. The inner and outer verticals are normal, the occipito-central a mere hair, the occipito-lateral not

present. The ciliæ of the posterior orbit and the hair of the occiput are as in the male. Posterior orbit yellow pollinose.

In both sexes the ground color of the bucca varies from a rather pale yellow through orange, brownish yellow and brown to almost black. It is always covered with yellow pollen, and quite thickly beset with whitish or yellow hairs, which are much longer toward the occiput. Its cephalic border has a row of small bristles.

The gena has a yellow ground color and is thickly yellow pollinose. It has no bristles.

The vibrissal ridges have a yellow ground color and thick yellow pollen. The vibrissal angles are somewhat dorsad the mouth edge and distinctly convergent. There are no large bristles except the principal vibrissa, but dorsad this the ridge is rather thickly beset on its lateral surface with exceedingly minute bristles or hairs.

The antennæ are yellow, with the cephalic border and lateral surface brown. The third joint is 1 mm. long, and the second 0.3 mm. The arista is thickly plumose to its very tip; its rachis is yellow on its thickened basal half, the rest appearing black.

The palpi are yellow, with black bristles. The halteres are yellow.

The thorax presents varying shades of metallic blue, green, and purple. The dorsum has three broad but very faint, almost black, stripes, one in the median line and one on each side just laterad the line of the dorso-central bristles. The extreme cephalic end of the thorax is white pollinose, even the humeri presenting this appearance by a sufficiently oblique light. The prostiga is light brown to dark brown; not at all a prominent object. The chætotaxy of the thorax is shown in figure 5. The dorso-centrals have precisely the same arrangement and variations as in *C. segmentaria*. The squamula thoracalis has its caudal half black, with a light border, and its cephalic half white; its dorsal surface is hairy, some of the hairs appearing black and some white. The squamula alaris, with the wings folded, is blackish on its mesal half or more and white on the remainder. On its dorsal surface, at the extreme lateral border, is a tuft of black hairs. The wing is shown in figure 6. It is mostly hyaline, but the base is

blackish about to the distal end of the small basal cells. The third vein is spinose about half way to the small cross-vein.

The abdomen is metallic purple in all the specimens before me, but this is in all probability subject to the usual variations of the Calliphorinæ. The first segment and a fascia on the caudal borders of the second and third segments are much darker, almost black. With a very oblique light the abdomen appears almost everywhere whitish pollinose. There are no bristles on the first segment. The second and third segments have each a marginal row of slender appressed bristles, which are larger toward the sides of the segments. The fourth segment has both marginal and discal bristles.

The legs vary in color from brown to black. Their bristles are as in *C. segmentaria.*

For the excellent drawings of the wings which accompany this and the following papers, I am indebted to my friend, Dr. Emma H. Wheeler.

MUSCINÆ MUSCIFORMES.

Morellia bipuncta Fabr.

Seven males and two females; Chapada; no dates.

Agrees with Wiedemann's description, to which I wish to add the following:

The color of the face varies in different individuals, and, according to the incidence of light, from yellow through brown to black. The bucca and vibrissal ridge are wholly polished. The gena is polished, except for a small white pollinose patch near its dorsal third. The ventral half or so of the posterior orbit is white pollinose; in the female the dorsal half and the vertex is metallic green; in the male the posterior orbit, owing to the greater occipital extension of the eye, only exists along the ventral half of the occipital border of the eye. The antennæ in most of these specimens are brownish yellow rather than brownish red, and the third joint is more or less pollinose; the arista is only sparsely plumose and has a yellow rachis; the third antennal joint is hardly more than twice as long as the second. While many male Muscinæ have an area of enlarged facets on the cephalic surface of the eye, this species stands out prominently as having an area with facets very much larger than in any other species known to me, some of them measuring as much as one-twentieth of a millimeter.

The front of the male is linear in the middle, expanding both dorsad and ventrad. Ventrad the linear part the geno-vertical plates are whitish pollinose and bear about four pairs of transfrontal bristles. Dorsad the linear part are about three pairs of transfrontals. All these bristles are very small. The great ocellar bristles are hardly distinguishable by size from the lesser, and the whole ocellar group, including the postvertical, are very small. The inner vertical is of good size, the outer vertical small, the occipito-central present. The cilia of the posterior orbit are very small.

The front of the female is about one-third as wide as the head, and broadens slightly from the antennæ towards the vertex. The geno-vertical plate is polished except on the lateral half or less of the ventral third, which is yellow pollinose. There are about eight transfrontals. Laterad the ocelli are a couple of pairs of bristles of small size, which point laterad. The bristles of the ocellar group are small, but the great ocellar pair is much larger than in the male. The inner and outer verticals are of fair size and about equal; the occipito-central is present. The cilia of the posterior orbit are longer than in the female.

The thorax looks as if finely punctate, and bears remarakbly few bristles, as is shown in figure 1. The variations are: (1) Usually only one humeral, but sometimes a second, much smaller; (2) the presutural is sometimes absent; (3) the second dorso-central is only sometimes present; it is smaller than the other; (4) the smaller of the two sterno-pleurals may be absent. It is, of course, possible that the variations mentioned may be due to injuries received by the specimens, but that is not my opinion. Not a single specimen has an anterior sterno-pleural bristle.

The only noteworthy bristles of the legs are as follows: Middle tibia, posterior surface near flexor border, one at junction of basal middle and a second at that of middle and apical thirds; hind tibia, lateral surface has three small flexors and one or two extensors, mesal surface has one or two extensors.

The wing is shown in figure 2.

I have very little doubt that *Pyrellia suspicax* Walk., Mexico, is the same as *Morellia bipuncta* Fabr. Van der Wulp thought that *Pyrellia iris* Bigot was the same as *P. suspicax* Walk. I am not prepared to affirm or deny this.

Morellia ochrifacies Rond.

Pyrellia ochrifacies Rond.
Pyrellia violacea R. D.
Cyrtoneura brevis Schin.
Pyrellia facilis Walk. (?)
Pyrellia basalis Walk., Jamaica (?)

Some of the specimens have the face brown, which, as Rondani himself points out, is the only difference between his *ochrifacies* and *violacea* R. D. That the names are synonymous there can consequently be no doubt. Desvoidy's name has priority, but the name "violacea" was already occupied for Fabricius's species, which belongs to this genus, and therefore Rondani's name must stand.

Schiner's description applies perfectly. I have specimens of the same species from the European dealers, Staudinger and Bang-Haas, labeled *Pyrellia ochricornis* Wied. Brauer and Bergenstamm include *Musca ochricornis* Wied. in the genus *Lucilia*, and as they had access to the type their opinion must be accepted.

The ground color of the epistoma, vibrissal ridge, transverse impression and gena is a yellowish red of varying shade, and all these parts, with appropriate incidence of light, appear more or less thickly yellowish pollinose. The cephalic fourth, third, half or even more of the bucca has the same ground color; the rest of it is black or brown, and the whole, with appropriate incidence of light, looks thinly white pollinose.

The dorso-ventral diameter of the bucca is 0.4 mm.; of the head, 2.1 mm. The bucca is rather thickly beset with black hairs, which are larger towards the occiput, and at the edge of the mouth opening assume the form of rather delicate bristles. The vibrissal ridge has ventrad the principal vibrissa several smaller vibrissæ, and dorsad the principal vibrissa one small vibrissa, while the whole lateral surface of the ridge is beset with very minute bristles. Gena naked.

The front of the male is narrow on the middle third, but even here the geno-vertical plates show distinctly as narrow pollinose lines, and the series of transfrontal bristles is not interrupted as it is in *M. bipuncta*. Dorsad the narrow part the front widens to the vertex, ventrad it widens to the antennal insertion. The geno-vertical plate is pollinose on its ventral two-thirds and black but not polished on its dorsal third. The vertex is black or brown, not polished. The great ocellar bris-

tles are small and almost parallel; the lesser ocellar, including the postvertical, very tiny. The inner verticals are large, the outer verticals smaller but distinct, and the occipito-central of good size. The cilia of the posterior orbit are shorter than in the female, and I can see but one row of bristles on the occipital surface parallel to them. The posterior orbit is white pollinose and, as is usual in the male, its dorsal half is obliterated by the greater development of the eye.

The front of the female is about one-fourth as wide as the head (0.7 mm. and 2.7 mm.). The vitta is about one-third the width of the front and is of a dark brown color with more or less of a reddish tinge. It is somewhat narrower towards the antennæ and broader towards the vertex. The ventral two-thirds of the geno-vertical plate is yellow pollinose, the dorsal third polished black or brown, and only with a particularly favorable incidence of light looks even thinly pollinose. There are about eight transfrontal bristles and laterad these, at the usual level, two or three small proclinate orbitals. On the dorsal third of the geno-vertical plate are also a number of minute hairs. The vertex is polished black or brown. The great ocellar bristles are of fair size; the lesser ocellars, including the postverticals, number from four to six pairs. The inner and outer verticals are normal, the occipito-central long, and the occipito-lateral is not present. The cilia of the posterior orbit are black and form a complete, well-aligned row. Parallel to the latter, on the occipital surface, I can see at least the beginnings of two more rows of small bristles. The posterior orbit is yellowish-white pollinose.

The antennæ and the base of the aristal rachis are yellow, varying in different individuals toward orange yellow or brownish yellow. The tip of the rachis and the hairs of the arista look black. The third joint of the antennæ is about twice as long as the second, and the arista is longer than the second and third joints together. The palpi are yellow.

The thorax is metallic blue, green, or violet, with a very broad, distinct median pollinose band, which begins at the cephalic border and does not reach caudad beyond the transverse suture. A similar but much fainter pollinose band can be seen on and just dorsad each humerus. Looked at with a very strong light and very obliquely, these bands seem much

more extensive, and, indeed, under these conditions, almost any point on the dorsum may be made to look pollinose. The prostigma is brown to black. The bristles of the thorax are represented in figure 3. The third dorso-central bristle is very small and may be absent.

The legs are brown to black. The only noteworthy feature of the bristles of the femora is at the apex of the middle one. Here we find in the female that the usual transverse apical group consists of about four members, of which the one most caudad is much the stoutest; these bristles in the male are all stouter than in the female, and we find in addition a peculiar structure, viz., a sort of tubercle, situated apicad the transverse group, bearing several short, stout, curved spines closely set and projecting apicad. Anterior tibia has no unusual bristles. The middle tibia of the male, as is so common in this genus, presents something of interest on the anterior surface close to the extensor border which is absent in the female. This is a row of small bristles extending from base to apex. The bristles of the basal half millimeter or so are stout compared with their length—genuine though very tiny spines; then they become longer and more slender, gradually changing their character almost to that of hairs. This is almost precisely the arrangement found in *Morellia violacea* Fabr., the difference being that in the present species the tiny spines of the basal portion of the series are arranged in at least two rows, while in *violacea*, as far as my material shows, they form but one row. The posterior surface of this tibia bears in both sexes the following: Two bristles in the basal third, one in the apical third very near the flexor border, and either one or two a very little basad the latter and farther away from the flexor border. The hind tibia differs in the two sexes. In the male, we find on the lateral surface near the flexor border a row of about five long bristles, beginning very near the middle of the tibia and extending to the apex; in the female there is a similar row, but its members are smaller, and there are usually four instead of five. On the same surface, near the extensor border, we find in the male a complete row from base to apex; the basal members are small, those toward the apex larger; four or five of the members of this row are much larger than the rest, but it is not always the same bristle which has attained the superior size. The same row exists in the female, but it is much less conspicuous, its members being

smaller and more delicate, and only one or two of them reaching the dignity of macrochætæ. On the mesal surface near the flexor border there is a series of long hairs, corresponding to the row of bristles on the lateral surface near the flexor border; this row is not present in the female. In both sexes, near the extensor border of the mesal surface is a row of from three to five long, strong bristles which are rather longer in the male. The bristles of the hind tibia of *M. violacea* Fabr. have a very similar arrangement, but are less numerous and more delicate; moreover, those near the flexor borders are limited to the apical third instead of extending over the apical half or more, and the extensor row of the lateral surface of the male is by no means so well marked and complete.

The abdomen is of the same color as the thorax. It has no macrochætæ except on the fourth segment and at the extreme lateral borders of the first and second. The color of the squamulæ varies. The squamula thoracalis may be opaque, black, dark brown with a yellowish brown border, or light brown with still lighter border; the squamula alaris may have a black border and a center which is hyaline with a blackish tinge, or it may have no border at all and be almost hyaline with more or less of a yellow-brown tinge. The halteres are yellow or yellowish brown.

The wing is shown in figure 4. The third vein is spinose its entire length, the spines being stouter and closer together basad the small cross-vein. In neither male can I see any spines apicad the small cross-vein, which may be due to their having been broken off or being much appressed, or may be a difference between the sexes.

Length, 6 to 7 mm.

Morellia violacea Fabr.

Musca violacea Fabr., Wied.
Cyrtoneura violacea Fabr., Brauer and Bergenstamm.
Pyrellia violacea Fabr., van der Wulp.
Pyrellia maculipennata Macq.
Cyrtoneura maculipennata Macq., Townsend's Catalogue.
Pyrellia maculipennis Macq.
Pyrellia specialis Walk.
Pyrellia centralis Lw.

Four males and four females; Rio de Janeiro, July and August; Rio, November, no date.

In an article on "Some Muscinæ of North America," Bio-

logical Bulletin, vol. 1, No. 1, I included *Pyrellia suspicax* Walk., *P. basalis* Walk. and *P. iris* Bigot among the synonyms of *violacea* Fabr. By the time the reprints reached me I was in doubt as to these three species, and so indicated in the copies sent out to my correspondents. Further study has convinced me that in all probability *suspicax* Walk. is *Morellia bipuncta* Fabr., *basalis* Walk. is *ochrifacies* Rond., and that *iris* Bigot is doubtful.

The wing of this species is shown in figure 6, and the thoracical chætotaxy in figure 5.

Morellia nigricosta, nov. sp.

Two males and three females; Chapada; November and January.

Dark metallic blue, green, or purple, with scarce a trace of pollinose coating even by the most oblique light. Abdomen without macrochætæ. Legs brown to black. Bucca wholly black and shining. Antennæ, palpi and halteres yellow. Wing with a dark brown mark along the costa, the transverse veins clouded with brown, and these clouds joined by an oblique brown band; third vein with only three to five spines, all at the extreme base. Length, 6 to 8 mm. Dorso-ventral diameter of head, 1.7 mm.; of bucca, 0.4 mm.

The head of the male is almost precisely like that of *M. ochrifacies* Rond., the only differences being (1) Third antennal joint longer, being nearly three times the second; (2) arista less densely plumose; (3) bucca wholly black and shining, not appearing at all pollinose, whatever the incidence of light; (4) the gena is considerably narrower; (5) the great ocellar bristles are divergent; (6) the outer verticals are not differentiated; (7) the ciliæ of the posterior orbit are less well developed, and on the occiput, parallel with them, I can see no rows of bristles. The head of the female has a width of 2.7 mm., and the front, at the narrowest part, which is at the junction of the ventral and middle thirds, measures 0.6 mm. From this narrowest point the front widens a very little toward the antennæ and considerably toward the vertex The bucca is like that of the male. The ventral third of the geno-vertical plate, the gena, the vibrissal ridge and the ventral half of the posterior orbit are silvery white pollinose. The dorsal two-thirds of the geno-vertical plate, the vertical, the occiput, as far as I

can see it, and the dorsal half of the posterior orbit are polished metallic green. The bristles of the head show only the following slight differences from those of the female of *M. ochrifacies* Rond.: (1) The orbitals are still smaller; (2) the occipito-central is smaller; (3) on the occiput, parallel to the ciliæ of the posterior orbit, there is but one row of bristles. The antennæ are yellow, inclining more or less to brown, especially on the third joint.

The thorax and abdomen are dark metallic green, blue, or purple, with scarce a trace of pollinose coating whatever the incidence of light. The abdomen has no macrochætæ even at the lateral borders of the segments. The bristles of the thorax are represented in figure 7. They are mostly small. The third dorso-central may be absent. The discal scutellars number from one to three; occasionally one of them is nearly as large as the apical and then the others are suppressed; occasionally again one of them is nearly or quite marginal. It is notable that at the cephalo-ventral angle of the meso-pleura there are no large bristles, but merely a clump of hairs. The legs vary in color from brown to black. The tibiæ are often lighter in color than the femora. The bristles of the femora are quite long and strong, but show no peculiar arrangement. The anterior tibia has no bristles in either sex, save the usual preapical of the extensor border. The middle tibia is alike in both sexes; its anterior surface has no large bristles and no peculiar arrangement of minute spines; its posterior surface has near the flexor border one large bristle at the middle and one at the junction of the basal and second fourths; it also has near the extensor border on its apical third from one to three smaller bristles. Hind tibia of male has on its lateral surface near the flexor border a row of six or seven short, almost equidistant bristles, which begins at about the junction of the basal and middle thirds and extends to the apex; on the lateral surface near the extensor border is a complete row from base to apex of mostly small, unequal sized but almost equidistant bristles; on the mesal surface near the extensor border is a not at all prominent beard of short, soft hairs which extends the whole length of the tibia, but is much longer on the middle two-fourths of its extent than elsewhere; on the mesal surface near the extensor border there is one bristle at the junction of the basal and second fifths. The

hind tibia of the female has on the lateral surface near the flexor border a row of four or five bristles, which occupy the middle third or middle two-fourths of the tibia and are smaller than those of the male; on the same surface near the extensor border there are four or five unequal and not equidistant bristles; on the mesal surface near the flexor border there are no bristles or hairs, and on the same surface near the extensor border there is one bristle, just as in the male.

The wing is represented in figure 8. On both surfaces, at the extreme base of the third vein, are from three to five small spines.

The squamulæ are white, nearly hyaline, but the squamula thoracalis has more or less of a brown tinge, and a part at least of its dorsal surface is very finely but densely pubescent.

Pyrellia sarcophagina v. d. Wulp.

Morellia sarcophagina v. d. Wulp, Biologia Centrali-Americana, Mexico.

One male; Corumba; May.

It is evident to one who studies Mr. van der Wulp's writings on the Muscinæ that for him the chief distinction between *Morellia* and *Pyrellia* is the metallic color of the latter genus and the non-metallic color of the former. Thus, he includes *violacea* Fabr. and *scapulata* Bigot in *Pyrellia*, but assigns the present species to *Morellia*. This is a grave error. Structural, not colorational, differences must be used for generic separation. The characters which separate *Pyrellia* from *Morellia* are only two: First, and much the most important, *Pyrellia* has a large bristle on the flexor surface of the middle tibia which is never present in *Morellia;* second, *Pyrellia* has (in all the species known to me) the sterno-pleural bristles arranged 1 : 3, while in *Morellia* these are 1 : 2 (in *M. bipuncta* Fabr. 0 : 2). From the structural standpoint this species must be assigned to *Pyrellia*.

The bristles of the throax are represented in figure 9. Owing to the position in which the legs have dried it is impossible to get a perfect view of the bristles which protect the prostigma; there may be others than those indicated in the diagram. The bristles of the legs are not particularly described by Mr. van der Wulp. The femora are as usual in this genus, as is also the anterior tibia. The middle tibia has on the anterior surface no bristles; on the flexor surface, one large one at junction of apical and

middle thirds; on the posterior surface four, about equidistant, and much smaller than the one on the flexor surface. The hind tibia has on the lateral surface near the flexor border four rather slender bristles; on same surface near the extensor border there is a complete row from base to apex of unequal but almost equidistant bristles, most of which are small, but about four are of good size; on the mesal surface near the flexor border there are no bristles; near the extensor border there two, one at the middle and the other at the junction of the middle and apical thirds.

Graphomyia maculata Scop.

Two males and two females; Desteno, December; Chapada; Piedra B., April; Corumba, May.

The specimens are precisely like those found in the United States. I consider *G. americana* R. D., *G. americana* Schin. and very likely also *Musca stipata* Walk. as synonyms.

Musca domestica L.

One male; Rio de Janeiro; July.

MUSCINÆ ARICIÆFORMES.

MUSCINA.

The separation into genera of the group *Muscinæariciæformes* is by no means satisfactory even to-day. *Myospila, Muscina, Clinopera, Aricia, Spilogaster* and *Limnophora* are all of doubtful extent and perhaps insusceptible of precise definition. Before this problem can be satisfactorily solved a much wider knowledge must be obtained than is at present in our possession. Of the four species in the collection before me which I think best to refer to *Muscina*, one has sparsely hairy eyes and sterno-pleurals 2 : 2, so that it might as well be referred to *Myospila* as to *Muscina*, but the hairiness of the eyes is so sparse and slight as to be very easily overlooked, in fact, has been overlooked, I think, by previous writers, and therefore I retain it in *Muscina;* another species agrees in almost every particular with *Clinopera;* and for a third a new genus might be erected, on account of the form of the wing.

Muscina brunnea, nov. sp.

One male; Corumba; May. Length, 7 mm.

Ground color of bucca, ventral part of occiput, posterior orbit, transverse impression of face, gena, vibrissal ridge, facial fossa, epistoma and antennæ pale brownish yellow; all these parts with more or less of a whitish or grayish pollinose coating, which is thickest on the very narrow genæ. The bucca is beset (not very densely) with black hairs, which, as usual, are longer toward the occiput. The principal vibrissæ are a little dorsad the free border of the clypeus. Ventrad the principal are several secondary vibrissæ. Dorsad the principal vibrissæ the vibrissal ridge is beset on its lateral surface with many exceedingly small, bristly hairs. The transverse impression and the gena are naked. The front is very narrow from a point just ventrad the ocelli to about its ventral third and then widens rapidly to the antennæ, forming a frontal triangle whose center, the vitta, is dark brown and whose sides, the geno-vertical plates, are grayish pollinose.

The geno-vertical plates are very narrow but bear an uninterrupted series of transfrontal bristles, which are, however, very small, especially at the narrowest part of the front, where they can only be seen with some difficulty. The black, vertical triangle is only large enough for the ocelli. All the bristles of the vertex are unusually small. The largest are the great ocellars. There are about four pairs of tiny lesser ocellars. I can make out, all about equal in size, the inner, outer and postverticals. The occipito-central and occipito-lateral bristles are absent. The cilia of the posterior orbit are short, but form a complete row; parallel to them, on the occiput, I can see no rows of bristles. The dorsal part of the occiput is black but white pollinose. The second antennal joint measures 0.2 mm.; the third joint, 0.7 mm. The arista is densely plumose, its rachis yellow. The dorso-ventral diameter of the head is 2.7 mm.; of the bucca, 0.3 mm. The palpi are pale brownish yellow.

The ground color of the thorax and scutellum is dark chestnut brown, with pale brownish-yellow humeri and prostigma. This ground color is obscured by a coating of grayish pollen, which, however, leaves certain stripes and spots of the ground color distinctly visible. These stripes and spots are best seen if one

holds the insect with its head towards him and looks vertically down upon the dorsum. Then one can easily see: (1) A faint median stripe which ends a little cephalad the scutellum; (2) on each side, somewhat mesad the line of the dorso-centrals, a stripe which is narrow and well defined cephalad the suture, but caudad the suture becomes broader and less well defined and fades out before reaching the scutellum; (3) on each side, cephalad the suture, laterad the dorso-centrals, mesad and caudad the posthumeral bristle, a triangular spot; (4) on each side, caudad the suture, laterad the dorso-centrals, and mesad the line of the intra-alar bristles, a short stripe, which reaches neither the suture nor the scutellum; (5) on each side a few other small, irregular spots not symmetrically situated. The chætotaxy of the thorax is represented in figure 10. The halteres are pale brownish yellow. The squamulæ are almost hyaline, with a slight brown tinge; their borders are narrowly dark brown and their marginal pubescence pale.

The abdomen has the same brown ground color as the thorax and the same grayish pollinose coating. The ground color shows through the pollen around the bases of the small hairs in such a way as to produce the appearance of a gray pollinose abdomen densely punctuate with brown. The first segment of the abdomen has a marginal row of small, appressed bristly hairs which are rather larger toward the sides of the segment. The second segment has a similar row of larger, less appressed bristles. The third segment has a similar row of still larger, not at all appressed bristles, and in addition, toward each side of the segment, on the disc, a row of three or four nearly erect, delicate bristles. The fourth segment has both a marginal and a discal row of erect, delicate bristles.

The legs and the pulvilli are wholly brownish yellow. The bristles of the anterior femora are as usual in this genus. The anterior tibia has the usual preapical of the extensor border, and at the same level, on the mesal surface, very near the former, another preapical bristle. The middle femora have no noticeable bristles except the transverse apical group, which consists of only two members, both distinctly on the posterior surface of the limb. The middle tibia has no bristles on either the anterior or flexor surface; on its posterior surface there are two, one at the middle and the other at the junction of the third and

apical fourths. The hind femur has its bristles arranged as usual, but they are shorter, more delicate and more numerous than usual, so as almost to give the impression that the femur has a soft, short beard on both the extensor and flexor borders. The hind tibia has on its lateral surface, near the flexor border, three short, delicate bristles, all in the middle third; on the same surface, near the extensor border, there are two stouter bristles, one at the junction of the basal and middle, the other at the junction of the middle and apical thirds; on the mesal surface, near the flexor border, there are no bristles, and near the extensor border only one, and that small, not far from the middle; the usual large preapical of the extensor border is present.

The wing is very faintly brownish yellow, the color being most pronounced toward the costa. The small cross-vein is very distinctly, the hind cross-vein almost imperceptibly, clouded with brown. The third vein is spinose about half way to the small cross-vein.

Muscina pallidicornis Bigot.

Two males and four females; Rio de Janeiro, July; and Chapada, no date.

Bigot had the female only. The specimens agree with Bigot's very insufficient description, except as to color of palpi and width of front. He says in his Latin description "palpi fusci," and in his French "palpes noires." In all my specimens the palpi are neither brown nor black, but of an orange-yellow color. They are, however, so thickly beset with black bristles that unless examined with care and in a good light it is easy to mistake their color for brown or black. Again, Bigot says the front is wide. The measurements are: Width of head, 2.6 mm., of front, 0.7 mm., which I should not call wide. This is, however, merely a matter of personal experience. If the species should turn out to be a new one, I would suggest for it the name *Muscina americana.*

The eyes are minutely and sparsely hairy. The dorso-ventral diameter of the head is 2 mm.; of the bucca, 0.2 mm. The ground color of the bucca, facial fossa, gena, geno-vertical plate, vitta, occiput and posterior orbit is black. All these parts, except the vitta, are pollinose; the occiput, posterior

orbit, bucca thinly so, and facial fossa, slaty gray; the gena and geno-vertical plate, silvery. The small lunula is silvery white. The vibrissal ridge seems to have a dark yellow ground color, but is so thickly gray pollinose that I can hardly feel certain. The principal vibrissa is on a level, very slightly dorsad the free border of the clypeus. Ventrad the principal are several secondary vibrissæ, and dorsad are a very few small hairs. The gena is naked. The bucca is thickly beset with black, bristly hairs, which are, as usual, larger toward the occiput, and form, along the edge of the mouth opening, a row of tolerably large bristles At the cephalic end of the bucca, along the ventral border of the transverse impression, is a row of about six tiny bristles, which, instead of having the usual direction of the buccal hairs, point caudad and more or less dorsad. A similar row, but of larger bristles, is found in certain species of *Hydrotæa* and *Pogonomyia*.

The front of the male is narrow, but not linear, and, moreover, its width is variable in different specimens, being twice as wide in one of my males as in the other. The frontal bristles form a complete series. They are largest at the ventral end of the front, and diminish in size as we pass dorsad, those nearest the ocelli being very small indeed. All are curved cephalad and dorsad, the convexity of the curve being cephalad. Of the bristles at the vertex, the great ocellars are the largest. They are almost parallel, and curve dorsad and cephalad; convexity of the curve dorsad. The other bristles at the vertex are mere hairs, but one can recognize from their position the inner and outer verticals, the postverticals, the occipito-centrals, and the usual tiny lesser ocellars. The cilia of the posterior orbit, except the first three or four, are short, but form a well-marked row. On the occiput, parallel to the cilia of the posterior orbit, are other irregular rows.

The front of the female measures 0.7 mm. in width; the head is 2.6 mm. wide. The sides of the front are perfectly parallel throughout. The vitta is about four times as wide as one geno-vertical plate, and either black or brown. The geno-vertical plate is silvery pollinose. The transfrontals number about eight, and are of very unequal size. About at the level of the anterior ocellus are two ascending frontals, the more dorsal much the larger. There are no orbital bristles, but lat-

erad the transfrontals on the geno-vertical plate are a good many exceedingly tiny, scattered hairs. The great ocellar bristles are large, and normal in direction. There are about four small pairs of lesser ocellars. The postverticals are large (about half as large as the inner verticals) and are not clearly members of the ocellar group; they are distinctly divergent. The inner and outer verticals are large. The occipito-centrals and occipito-laterals are both present. The cilia of the posterior orbit and the bristles on the occiput are as in the male. The eye of the female is less distinctly hairy than that of the male.

The ground color of the thorax is shining black, but it has several gray pollinose stripes and patches, and the meso-pleura, sterno-pleura and scutellum are quite uniformly but thinly gray pollinose. The distinctness of the stripes and patches varies in different individuals, and also according to the incidence of the light. They are as follows: (1) A broad median stripe. (2) A broad stripe on each side in the line of the dorso-centrals; both this and the former are most distinct cephalad the suture, and near the scutellum become broader and fainter and fuse with one another. (3) One on each side caudad the suture in the line of the intra-alars. There are also rather thick patches covering the humeri, and thin patches extending from the humeri to the roots of the wings.

The halteres are yellow or yellowish brown.

The squamulæ are almost hyaline, in some specimens with a faint yellowish-brown tinge and a distinctly yellow brown border.

The chætotaxy of the thorax is shown in figure 12. The second intra-alar is absent in both males and in one female, perhaps broken off, but I can see no scar. The supra-alars are unusual; the cephalic one is small, often so small as to be little or not at all distinguishable from the microchætæ; the caudal one varies in size, but is always distinct. The most dorsal humeral varies in size, always much smaller than the others; it is sometimes a mere hair.

The abdomen has a shining black ground color with a uniform coating of brown pollen, which is much thicker in the male than in the female, and in the female is thickest on the fourth segment. On each segment of the male there are marginal microchætæ, which are largely toward the sides of the

segment; all are appressed save those of the fourth and those toward the sides of the third. Toward the sides of the third segment there are three or four small discal microchætæ, and on the fourth segment in a complete row of discals. The female has about the same arrangement, but on the first two segments the bristles are mere hairs; on the third only one or two of the marginals. Those at the extreme sides of the segment are not appressed, and there are but one or two discals situated at the extreme lateral borders of the segment.

The legs vary in color from brown to black. The bristles of the fore leg are as usual in this genus. The middle femur presents the usual partial row along the center of the anterior surface from base to middle, ending with one prominent bristle; the preapical transverse group has three members, all on the posterior surface. The middle tibia has no bristles except two on the posterior surface; both are in the middle third, one near its base, the other near its apex. The bristles of the hind femur are as usual. The hind tibia has on the lateral surface near the flexor border one bristle near the middle (and in one male a second, much more delicate, a little basad the other), and near the extensor border a row, beginning a little basad the middle of the tibia and running toward but not to the apex; this row varies in number from three to five; possibly when less than five are present some have been broken off, but I can see no scars.

The palpi are orange yellow, thickly beset with short, coarse black bristles.

The antennæ are brownish yellow, with a thin pollinose coating; sometimes the color is paler, and sometimes, especially on the second joint and toward the apex of the third, darker. The third joint is almost or quite three times as long as the second. The arista is thickly plumose with long hairs, and its rachis is yellow at its base.

The wing is almost hyaline. In most specimens there is a very faint brownish-yellow color most pronounced along the second vein and near the costa. One or two specimens have the cross-veins faintly clouded with the same color. The third vein has from two to four spines at its base on both surfaces of the wing. The wing is shown in figure 13.

Length of body, 6 to 7 mm.

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Muscina varicolor, nov. sp.

One male, Chapada, no date; one female, Rio de Janeiro, July. Length, 6 to 7 mm.

The ground color of the whole head, antennæ and palpi is pale brownish yellow in both sexes, except that the frontal vitta of the female is black, and except, perhaps, the occiput and geno-vertical plate, which are so thickly pollinose that I cannot make out the ground color. The ground color of the whole head is somewhat obscured by a pollinose coating, which is silvery white on the facial fossa and geno-vertical plates and inclines to bluish gray on the occiput and posterior orbit, especially in the female.

The principal vibrissa is somewhat dorsad the free border of the clypeus. On the vibrissal ridge dorsad the principal vibrissa there are a few tiny bristly hairs, not reaching more than half way up the ridge. Ventrad the principal are two or three secondary vibrissæ.

The bucca and ventral portion of the occiput are quite uniformly, but not thickly, beset with black, bristly hairs, which do not in either sex form a distinct row of larger bristles along the lateral border of the mouth.opening. As usual, the buccal hairs are longer toward the occiput.

The cilia of the posterior orbit form a complete and well-aligned row in both sexes. They are rather longer in the female. The remainder of the occiput is remarkably free from bristles. I can only see one row which begins dorsad, a short distance ventrad the beginning of the cilia of the posterior orbit, and runs almost directly ventrad, as far as I can see.

The dorso-ventral diameter of the head of the male is 2.1 mm.; of the bucca, 0.3 mm. In the female these figures are 1.7 mm., 0.2 mm. The front of the male is very narrow on about its middle two-fourths, the eyes being separated only by the silvery line of the fused geno-vertical plates, and on this narrow portion there are no transfrontal bristles. Ventrad the narrow portion is the usual frontal triangle, which has a rich brownish-red center (vitta) and silvery sides (geno-vertical plates). Upon its sides are five pairs of transfrontal bristles, one of which is very much larger than the others. All curve cephalad and dorsad, with the convexity of the curve cephalad. Dorsad the narrow part is a narrow vertical triangle, on whose

sides ventrad the ocelli are two more pairs of transfrontal bristles. The bristles of the vertex are as follows: The great ocellars, small and parallel, as is usual in this genus; one large lesser ocellar pair, as large as any of the bristles of the vertex (a very unusual feature); one hardly visible lesser ocellar pair; the postverticals are not present; the inner and outer verticals and the occipito-central bristles are present and are small, as is usual in this genus.

The head of the female is 2.2 mm. wide. The width of the front is 0.6 mm. The sides of the front are almost exactly parallel throughout. The frontal vitta is between four and six times as wide as one geno-vertical plate. There are about five transfrontal bristles, two ascending frontals, and a good-sized pair of preocellars. There is nothing unusual about the bristles of the vertex; all are present, and of normal size and direction. There are no orbital bristles.

The length of the second joint of the antennæ is 0.25 mm.; of the third joint, 0.55 mm. The arista is thickly and long plumose, and the base of its rachis is yellow.

The chætotaxy of the thorax is shown in figure 14. The ground color of the thorax of the male is a pale yellowish brown, and it has everywhere a thin, yellowish pollinose coating. If looked at vertically there are faint suggestions of stripes in the dorso-central and acrostical lines. This yellow-brown ground color appears in the female only on the humeri and prothorax, on the base and tip of the scutellum, along the sutures bounding the meso-pleura and sterno-pleura, on the ptero-pleura, on the postalar callosity, and on the mesonotum, near the scutellum. The most of the thorax of the female has a black ground color and is covered with brownish or gray pollen, which forms three broad but rather indistinct stripes—a median and two lateral. I have observed that, when a species has two ground colors, as in this female, their relative extent is very variable in different specimens.

The abdomen of the male.—First segment: Pale brownish yellow with a dark brown transverse fascia on each cephalo-lateral angle; a marginal row of small appressed macrochætæ, which are larger towards the sides of the segment. Second segment: Most of the cephalic half and also a narrow median stripe are pale brownish yellow; the caudal half and two pro-

longations [from the same enclosing the narrow median stripe are dark brown; the yellow part, including the narrow median stripe, looks pollinose by very oblique light, but the dark brown part shows no pollinosity whatever the incidence of light; a row of marginal bristles larger than those of the first segment, the most lateral of which are not appressed; also a few small discals toward and on the sides of the segment. Third segment: At first glance seems wholly dark brown, but careful examination reveals a pattern just like that of the second segment, the part which was yellow on segment 2 approximating very closely the color of the dark brown part; the part corresponding to the yellow part of segment 2 looks pollinose with a favorable incidence of light; a row of marginal bristles, larger and less appressed than those of segment 2, and two or three discals toward and on the sides. Fourth segment: Wholly dark brown, with a certain amount of pollinose coating, through which, at the bases of the bristles, the ground color shows, producing a speckled appearance; a complete row of marginal and another of discal bristles.

The female abdomen is colored throughout like the fourth segment of the male. Its bristles are like those of the male, except that there are no discals on segment 2, only one on segment 3, and the row on segment 4 is broadly interrupted in the middle.

The legs of the male are brownish yellow; the hind femur is darker toward the apex; the tibiæ are darker than the femora; the hind tibiæ almost brown; the tarsi are black; the pulvilli are pale brownish yellow. In the female the femora are blackish brown, the tibiæ a little paler, the tarsi black; I cannot make out the color of the pulvilli.

This bristles of the legs.—The anterior femur is as usual in this genus. The anterior tibia has the usual preapical of the extensor border; on the same level, just laterad this, on the lateral surface, a second bristle, and close to the apex of the lateral surface a third. Middle femur has the usual anterior median partial row, which is here made up of equal equidistant bristles; the transverse apical group consists of one bristle on the anterior surface and three on the posterior surface. The middle tibia has no bristles except on the posterior surface, where we find, in the female, two—one at the junction of the

basal and middle, the other at that of the middle and apical thirds; the male has these two, and in addition a third, smaller, bristle, which lies between the other two, nearer the apical one. The hind femur is as usual in this genus. The hind tibia has three bristles; two are on the lateral surface, one near the flexor, the other near the extensor border, and the third is on the mesal surface near the extensor border; all three are near the middle of the tibia.

The wing of the female is shown in figure 15. The brown spots on the wing are smaller and less deeply colored in the male specimen. The first and third veins are spinose their entire length on both surfaces of the wing. The spines are more easily seen in the female.

The squamulæ have a faint brownish-yellow tinge, but are almost hyaline. The halteres are brownish yellow.

Muscina latipennis, nov. sp.

One female; Chapada; January. Length, 7 mm.

The ground color of the facial fossa, vibrissal ridge, gena, transverse impression of the face, bucca, occiput and posterior orbit is a pale brownish yellow. All these parts are pollinose—the occiput, bucca and posterior orbit grayish, the others whitish or silvery.

The bucca is extremely narrow, hardly reaching a level 0.1 mm. ventrad the ventral border of the eye. The bucca bears a row of stout bristles parallel to and a short distance from the lateral border of the mouth opening and also a few hairs.

The occiput is so closely applied to the thorax that I can see no bristles thereon except the cilia of the posterior orbit, which are normal.

The principal vibrissa is distinctly dorsad the free border of the clypeus. Ventrad the principal are two secondary vibrissæ. Dorsad the principal vibrissa on the vibrissal ridge there is first a small clump of minute bristly hairs, and from this a row of still more minute hairs (hardly visible with twenty diameters) extends dorsad three-fourths of the distance to the base of the antennæ.

The divergence of the mesal border of the eyes from the base of the antennæ ventrad is very slight, so that the sides of the

face seem almost parallel, which is a decided novelty in this genus. The genæ are naked.

The front, at its narrowest point, which is the ventral end, is about one-fourth as wide as the head. From this point to the vertex it widens slightly.

The geno-vertical plate is thickly white pollinose. It bears about eight transfrontal bristles, of which only three are long ones; the others are very small. Laterad the transfrontals are only a few minute hairs, no orbitals. There are two ascending frontals. The bristles of the vertex are all present and of normal size and dirction. The vitta is black, brownish at its ventral end, and bears no preocellar bristles.

The palpi are pale brownish color.

The antennæ are pale brownish yellow. The third joint measures 0.8 mm., the second 0.2 mm. The arista is very long, short plumose, its rachis yellowish at base.

Most of the dorsum of the throax has a dark brown ground color with a gray pollinose coating, which leaves the ground color showing clearly in certain places, viz.: (1) On each side, a trifle mesad the line of the dorso-centrals, a narrow stripe, which is distinct cephalad the suture, but caudad the suture becomes broader and less well defined, and fades out entirely before reaching the scutellum; (2) on each side, cephalad the suture, an irregularly triangular patch between the presutural, posthumeral and dorso-central bristles; (3) on each side, caudad the suture, a patch between the dorso-centrals and intra-alars. Now while most of the dorsum is as above described, we find that each of the four corners of the dorsum—*i. e.*, each humerus and an adjacent area, and each postalar callus and an adjacent area—is broadly pale brownish yellow, and there is a rather broad stripe of the same color just dorsad the notopleural suture and root of the wing. Moreover, all the visible part of the cephalic surface of the throax, the prostigma and most of the meso- and sterno-pleuræ have the same color. As I stated under *Muscina varicolor*, the extent of these yellow areas probably varies in different individuals. The chætotaxy of the thorax is shown in figure 16.

The abdomen has a dark brown ground color with a white pollinose coating, which, with a favorable incidence of light, looks quite thick. There are no discal bristles except on seg-

ment 4, which has one toward the side and one on the extreme lateral border. The marginal rows are mere appressed hairs on segments 1 and 2 and but little larger on segment 3; even on segment 4 they are not at all large.

The legs are dark brown, except the coxæ and apices of the femora, which are pale brownish yellow. The bristles of the anterior femora are as usual in this genus. The anterior tibia has a preapical group of three, viz., the usual one on the extensor border and two at the same level on the lateral surface, one of which is very near the extensor, the other very near the flexor border. The middle femur bears the usual anterior median partial row, all of which are small; the transverse apical group consists of three on the posterior and one on the anterior surface. The middle tibia has on its posterior surface, near the extensor border, a complete row of about equidistant bristles extending from base to apex, which are mostly of insignificant size, but two in the middle third and two or three near the apex are as large as the usual bristles of this surface in this genus. On the anterior surface of the middle tibia close to the apex is a bristle which, if normal, will at once distinguish this species from any other Muscid that I have seen; it is half as long as the tibia and projects cephalad, with a slight curve dorsad. It seems to me more probable that this is not a normal structure, but has been accidentally (or purposely) stuck on here, for the following reasons: (1) It is present only on one of the middle tibiæ, the other showing not even a scar at this point; (2) the anterior sterno-pleural bristle of the side where the strange tibial bristle is present has been broken off; (3) the remarkable tibial bristle is just about the same size as the anterior sterno-pleural bristle. The bristles of the hind femur are as usual in this genus. The hind tibia has no bristles on its mesal surface; on its lateral surface near the flexor border there are two bristles about at the middle, and on the same surface near the extensor border there is one at the same level.

The squamulae are white, almost hyaline.

The halteres are brownish yellow.

The wing is represented in figure 17. It is very broad for a *Muscina*, somewhat suggesting in shape that of a *Phasia*. The species does not, however, belong to *Phasiophana*. The crossveins are distinctly clouded with brown. There is a dark

brown area along the costa which begins at the apex of the stigma and reaches to the end of the second vein; this area extends backward as far as half way between the second and third veins. There is also a large but very faint brownish clouding of the apex which extends from the middle of the submarginal cell across the first posterior and half of the second posterior cells. This is very narrowly separated from the dark brown costal stripe and from the cloud on the hind cross-vein. The only spines on the veins of the wing are two or three exceedingly minute ones at the extreme base of the third longitudinal.

Brown. Antennæ, palpi, humeri, post-alar callosities and various patches on the sides of the thorax pale brownish yellow. Bucca linear. Sides of front and of face almost parallel. Only three dorso-central bristles caudad the suture. A peculiar row of bristles on the posterior surface of the middle tibia. Third longitudinal vein with only two or three spines, and these at the extreme base.

PLATE XXXVI.

A sketch of the lumbar region of one of the operated cats, showing the most important veins and changes instituted by ligation of the post cava at *l*. The overlying parts are removed, and the post cava turned to one side to expose part of its dorsal side.

a—Azygos.
b—Thirteenth rib.
c—First lumbar vertebra.
d—Pieces of the diaphragm.
e—Adreno-lumbalis, with its branches.
f—Left renal vein.
g—Vena spermatica.
h—Seventh lumbar vertebra.
i—Iliac communis.
j—Post cava, above ligature.
k—Right adrenal.
l—Point of ligation.
m—Anastomizing vessels in the ligated area.
n—Right renal vein.
o—The four lumbar veins.
p—Ilio lumbalis.

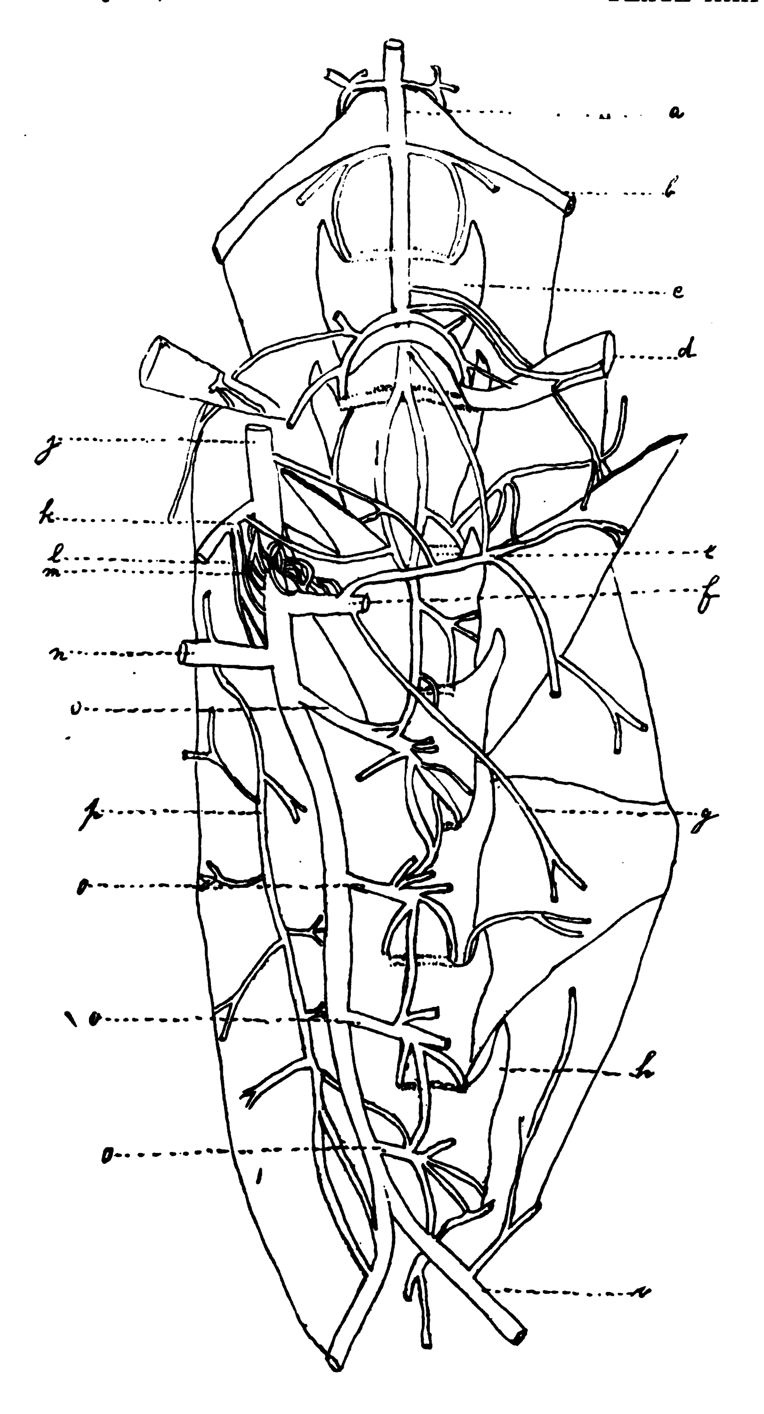
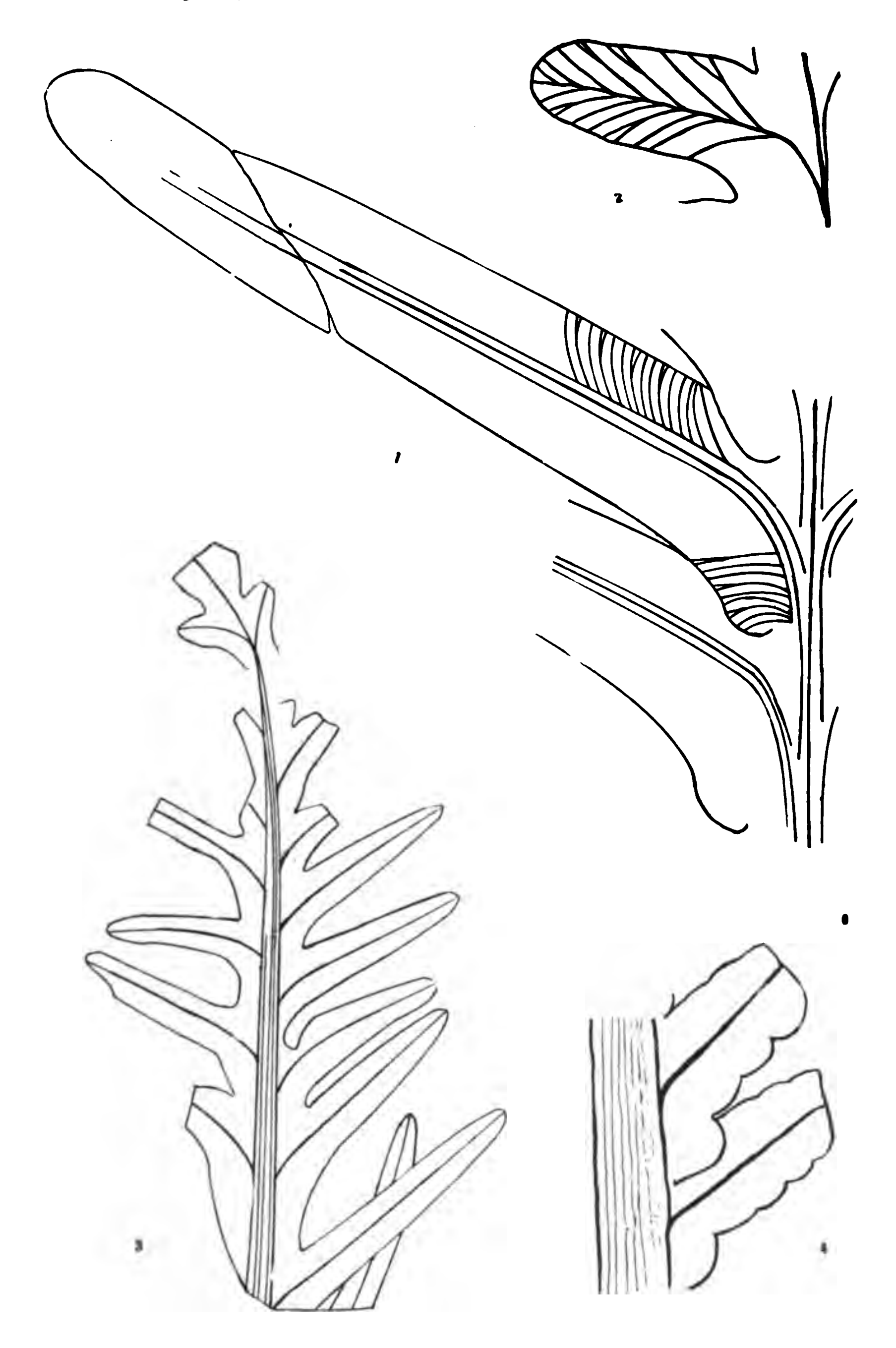

a
b
c
d
j
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l
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e
f
n
o
p
g
o
o
h
o
x

PLATE XXXVII.

Fig. 1.—A pinnule of *G. splendens*, sp. n. Natural size.
Fig. 2.—A pinnule of *G. simplex*, sp. n. Twice natural size.
Fig. 3.—*G. lineata*, sp. n. Natural size.
Fig. 4.—*G. ? lobata*, sp. n. Natural size.



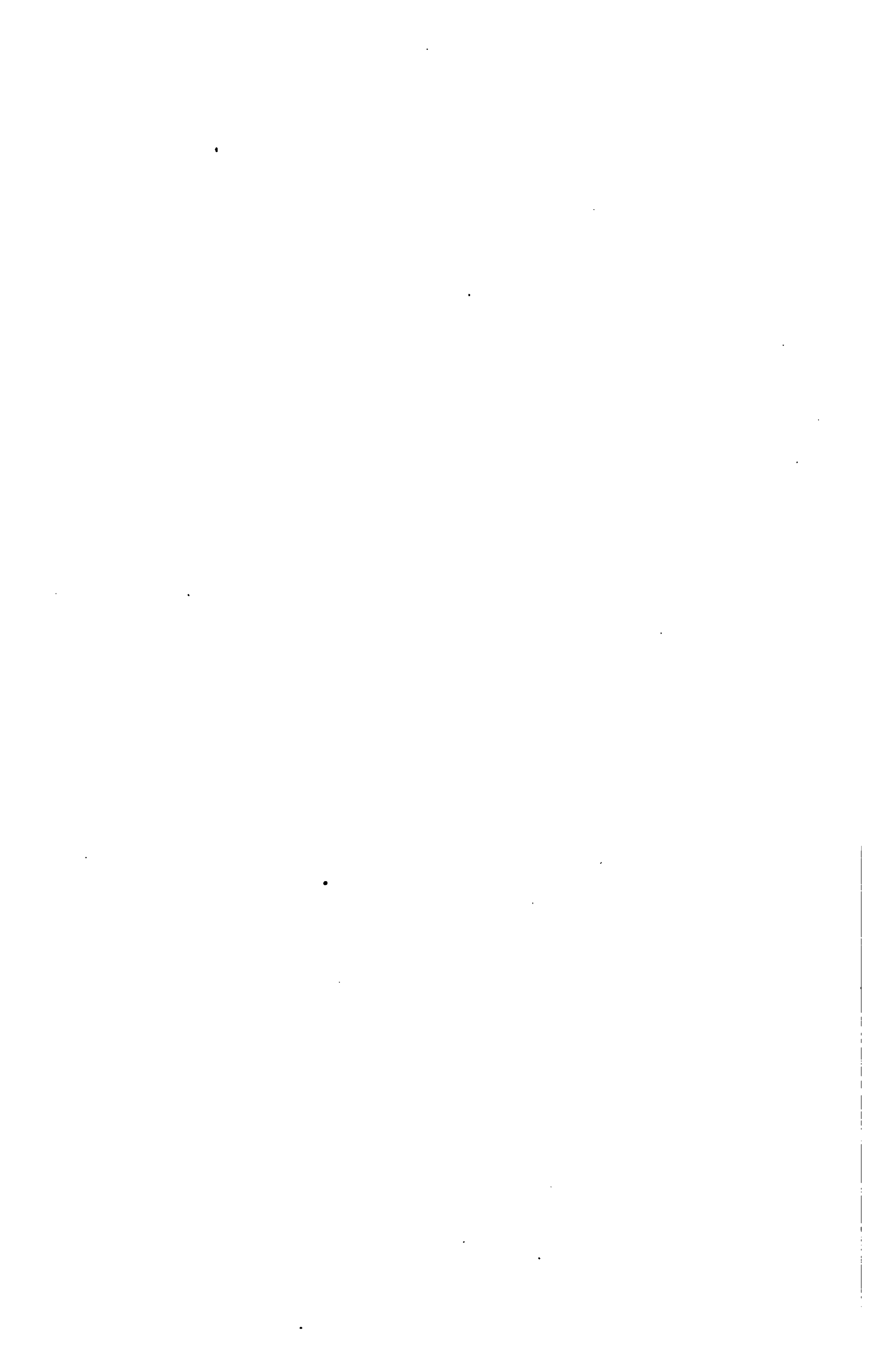
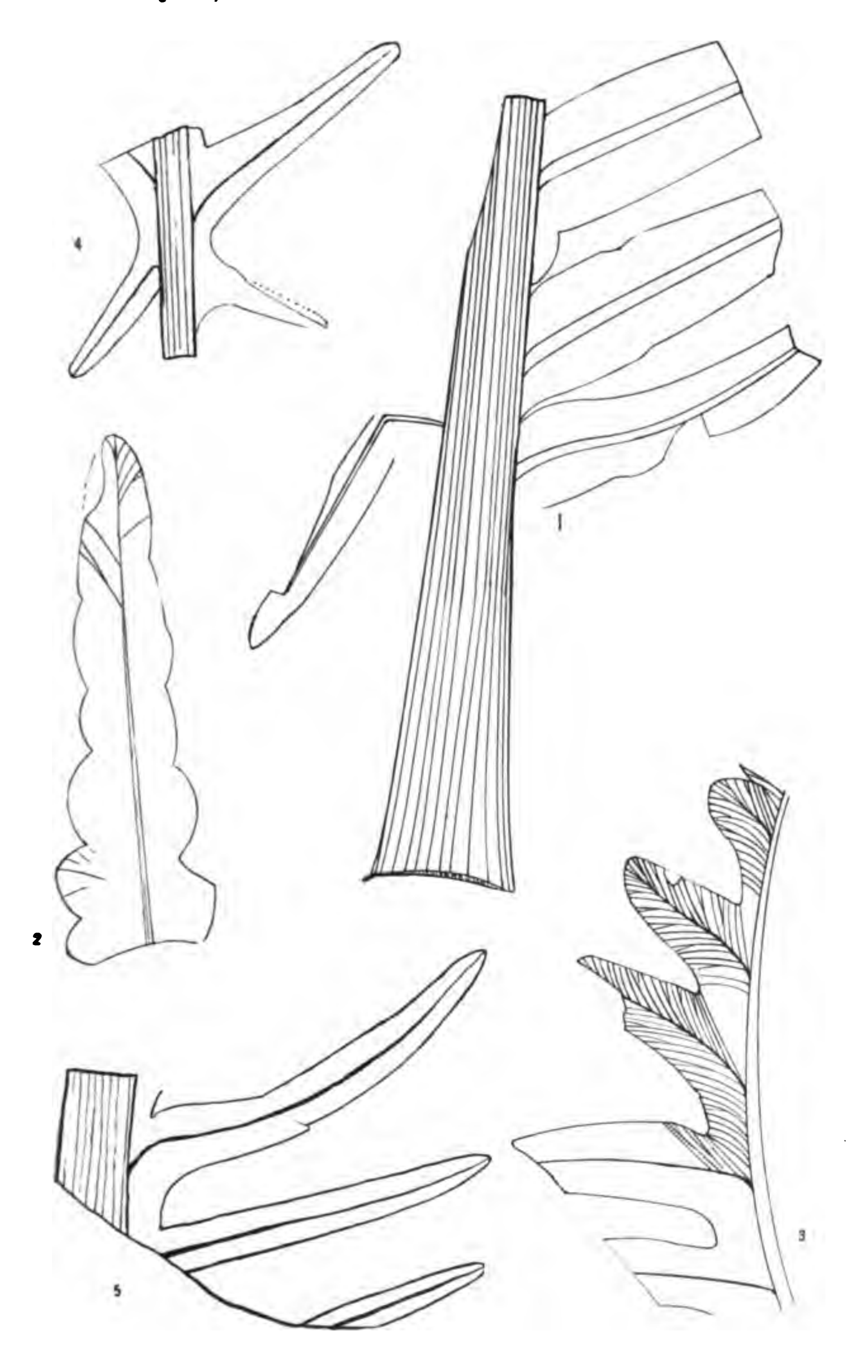


PLATE XXXVIII.

Fig. 1.— *G. splendens*, sp. n. Basal part of the frond.
Fig. 2.— *G. simplex*, sp. n. A large terminal pinnule.
Fig. 3.— *G. simplex*, sp. n.
Fig. 4.— *G. lineata*, sp. n. Base of the frond.
Fig. 5.— *G. lineata*, sp. n. Part of the frond from above the base.
All natural size.



4
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PLATE XXXIX.

Figs. 1, 2, and 3.—*G. simplex*, sp. n. All natural size.

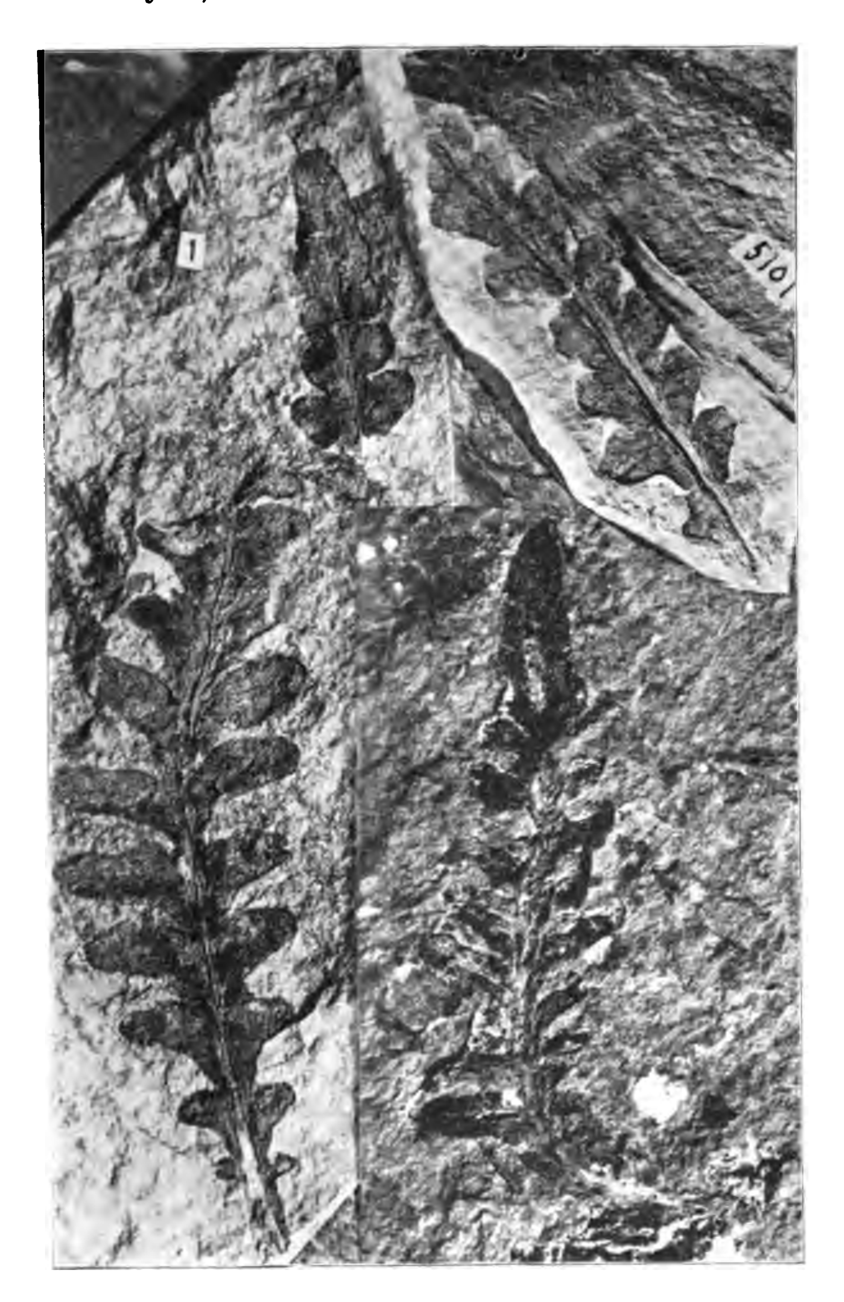

1
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PLATE XL.

G. splendens, n. sp. **Reduced to about three-sevenths natural size.**





PLATE XLI.

G. sterlingi, sp. n. A little less than natural size.





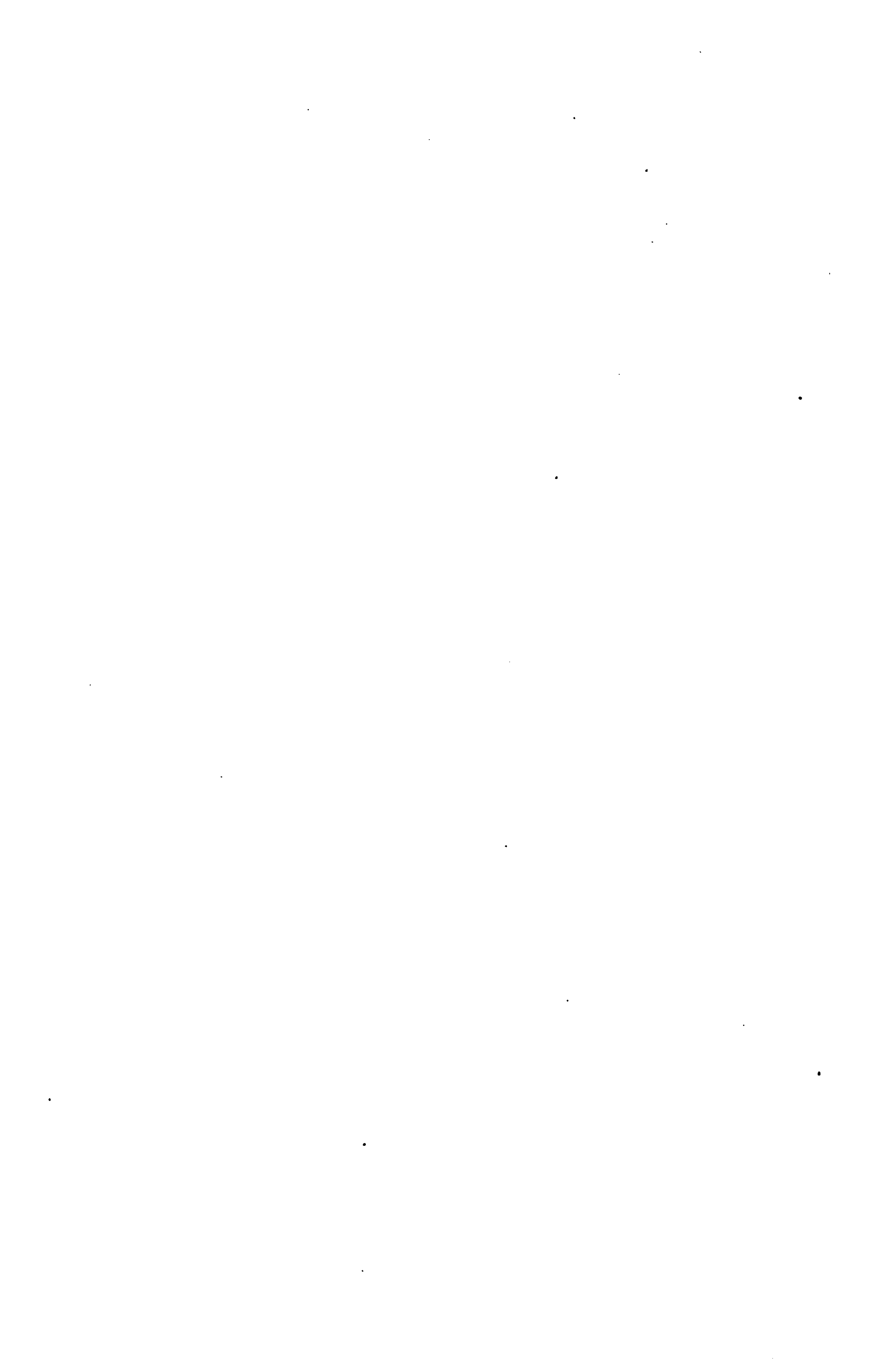


PLATE XLII.

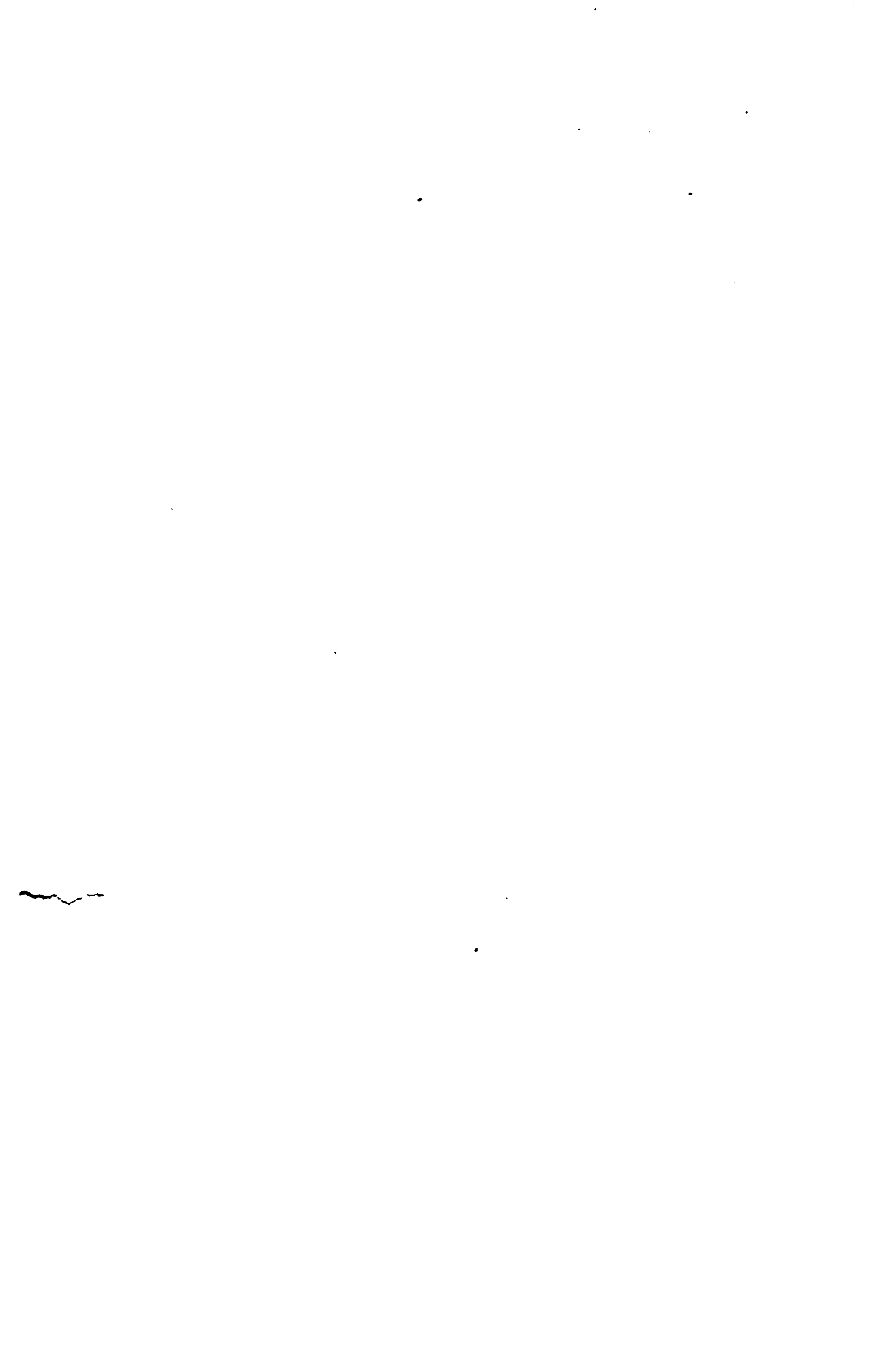
Fig. 1.— ***G. sterlingi*, sp. n.**
Fig. 2.— ***G. ? lobata*, sp. n.**
Both slightly reduced.



PLATE XLII.

Fig. 1.— *G. sterlingi*, sp. n.
Fig. 2.— *G. ? lobata*, sp. n.
Both slightly reduced.


1
2



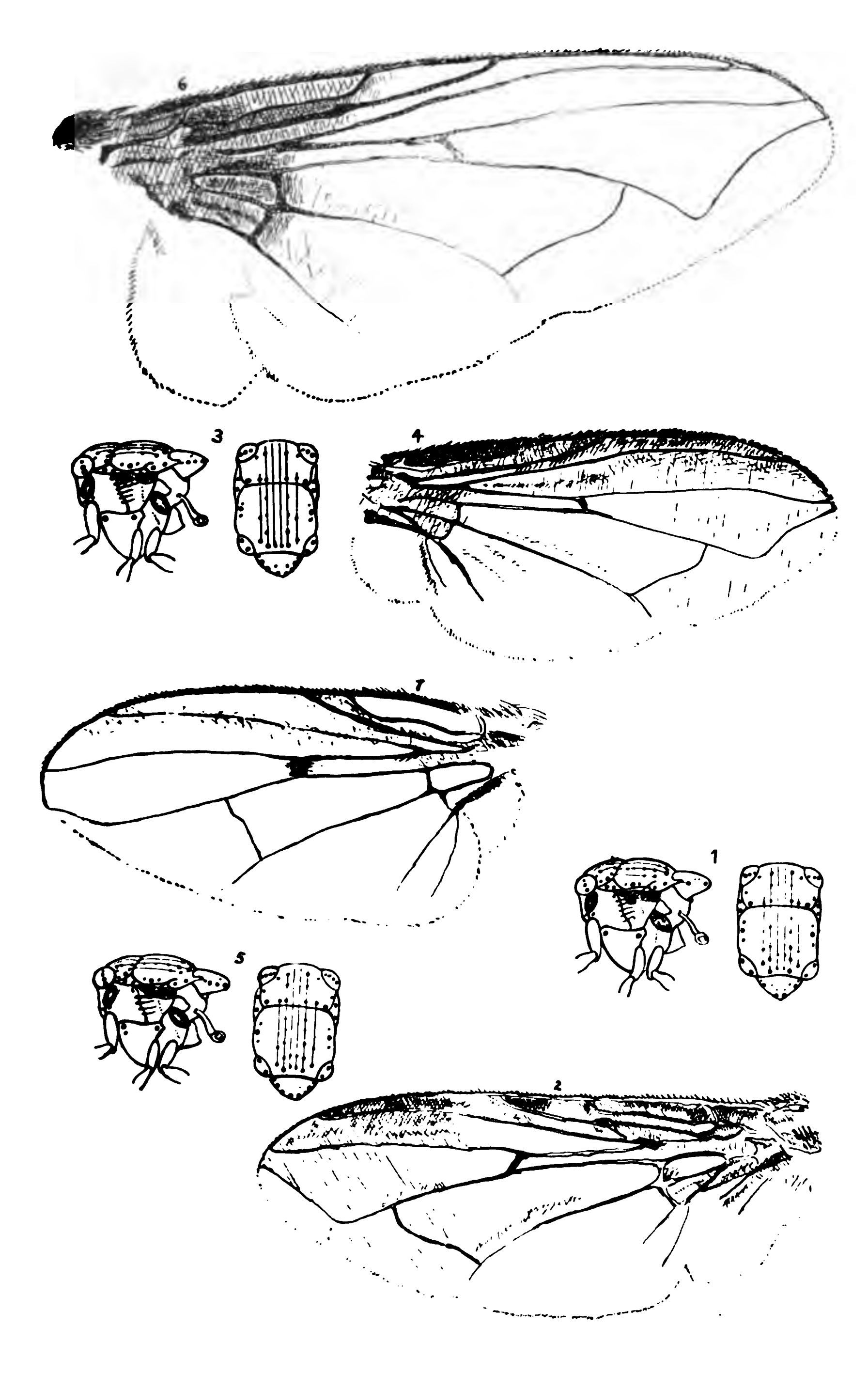
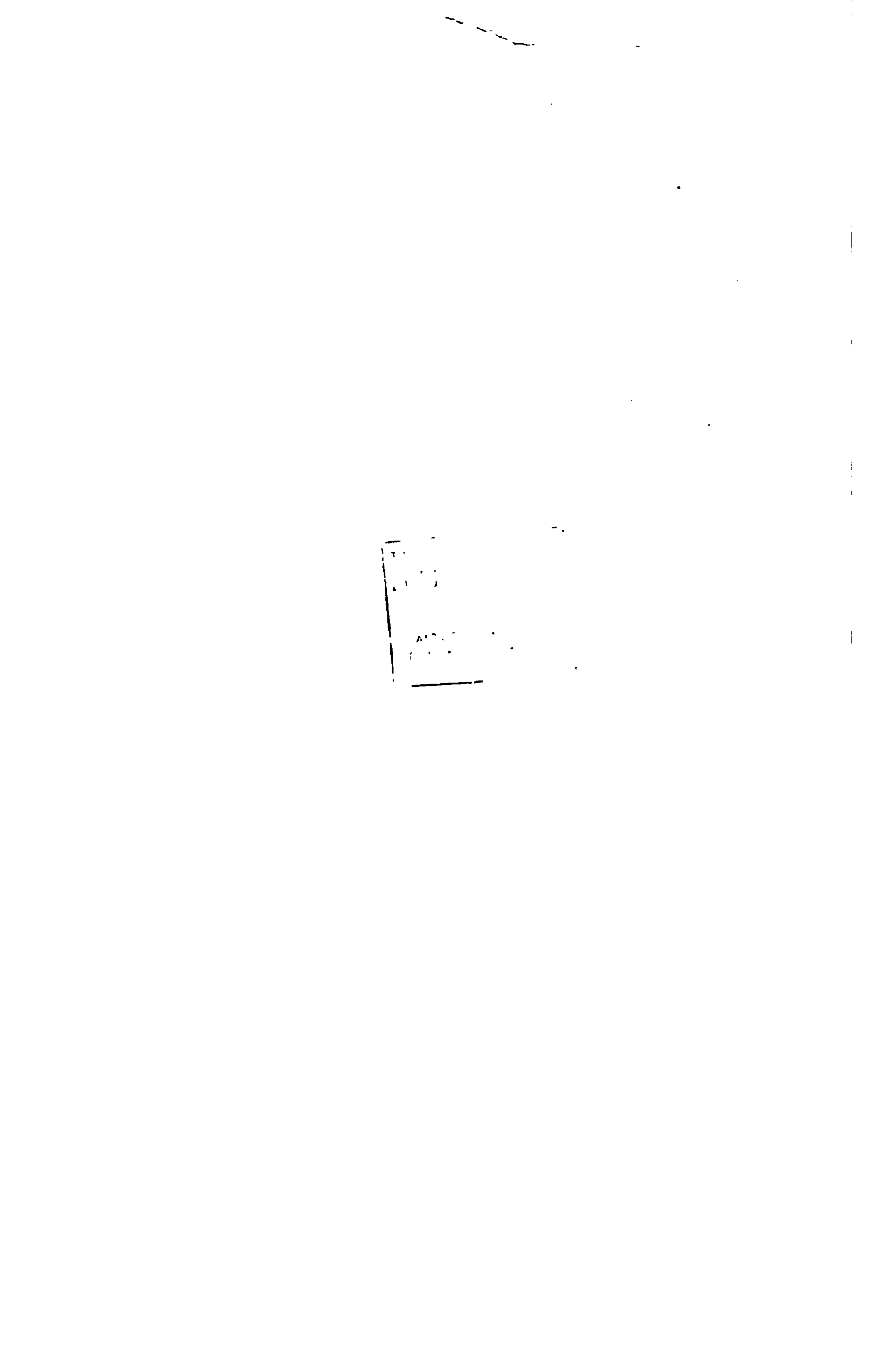
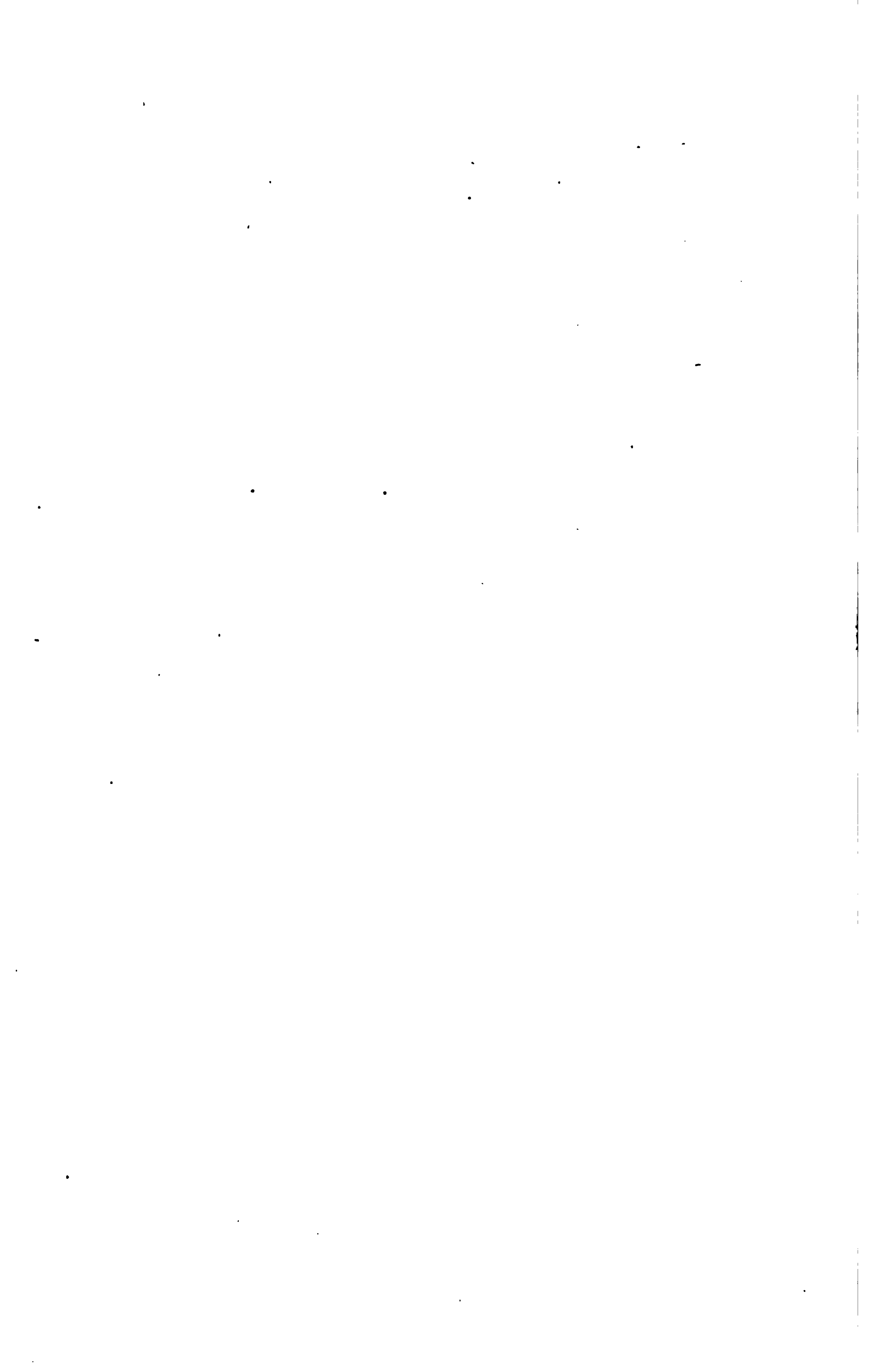
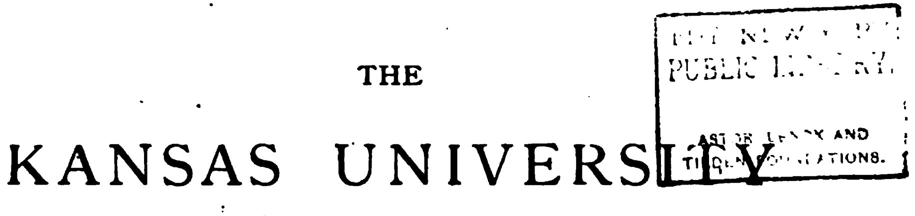

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7
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5
2



PLATE XLV.







THE

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SERIES A.—SCIENCE AND MATHEMATICS.

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VOL. IX. OCTOBER, 1900. NO. 4.

Coal Measures Faunal Studies. 1.

BY J. W. BEEDE AND AUSTIN F. ROGERS.

It is proposed by the authors, in a series of papers with the above title, to give lists of the faunas of the different horizons of the Coal Measures of Kansas and certain parts of western Missouri. The several papers will be written by the authors separately and each alone is responsible for the information contained therein. In the final paper, the joint production of the two authors, some generalizations as to the distribution of species in the Coal Measures will be attempted.

Several things have led to the production of this series. The faunal relations of the Upper and Lower Coal Measures is chief among them. At present there seems to be no sharp faunal break between them and no unconformity of strata, making a very careful study of the fossils of the entire range necessary. It will also serve as a check list, and, it is hoped, bring out fossils as yet unknown to the region which may throw additional light on the subject. In the third place it will assist greatly in determining the relationships between the faunas of the Permian and the Coal Measures. Careful collecting such as is necessary in a work of this kind brings to light fossils which would otherwise escape notice. This is particularly true of the range of the more inconspicuous species.

The lists are, of course, somewhat incomplete, yet it is believed that they represent the typical faunas of the several horizons at the localities mentioned.

The fossils herein listed are those collected by the authors or studied by them in the collections made by careful collectors, in which the specimens were carefully and accurately labelled.

The next number of the series will be on the fauna of the Shawnee, Wabaunsee, and Cottonwood formations, the remaining formations of the Coal Measures beneath the Permian, by Mr. Beede.

1. The Pottawatomie and Douglas Formations along the Kansas River.

BY AUSTIN F. ROGERS.

The Pottawatomie and Douglas Formations are names applied to the lower part of the Upper Coal Measures by Professor E. Haworth.[1] This paper deals with the fossil faunas of these formations as exposed along the Kansas river. The horizons range from the Bethany Falls Limestone at Kansas City, Mo., to and including the Upper Oread Limestone at Lecompton, Douglas county, Kansas.

The following table[2] shows the names used by the University geologists and the corresponding number used in the paper:

Douglas Formation—	Oread Limestones..	17–19
	Lawrence Shales...	16
Pottawatomie Formation—	Garnett Limestones	14–15
	Lane Shales.......	13
	Iola Limestone.....	12
	Thayer Shales.....	11
	Erie Limestones...	1–10

Broadhead,[3] in 1872, assigned numbers to the different horizons of the Coal Measures of Missouri. In the absence of detailed stratigraphic work it is impossible to correlate these completely with those of eastern Kansas. Yet where there is no doubt, as in the lowermost horizons exposed at Kansas City, Mo., Broadhead's numbers are given, followed by Br.

Bennett,[4] in 1896, studying the Coal Measure rocks of eastern Kansas, made sections at Kansas City, Mo., Argentine, Kansas, and other localities along the Kansas river. As far as they go these sections are used for the description of the horizons, the words of Bennett being used. The numbers used by Bennett in his Argentine section are given, followed by Be.

Alternating shales and unimportant limestones intervening between the prominent limestone systems are grouped together under one number. These numbers were simply for convenience of reference, as in the absence of detailed work over large areas the relative importance of the horizons is unknown.

1 Haworth. Univ. Geol. Surv. Kans., vol. III, p. 94.
2 Haworth. loc. cit.
3 Broadhead. Geol. Surv. Missouri. Prel. Rep. on Iron Ores and Coal Field. pp. 88 et. seq., 1872.
4 Bennett. Univ. Geol. Surv. Kans., vol. I, 1896.

The bryozoans are more prominent than is usual in lists of Coal Measure fossils, for the author has made a special study of them. They are certainly too much neglected. Descriptions of the bryozoans, which are here followed by the author's name, will be found in this journal[1].

Fossils, to which Beede or Beede and Rogers have given names, are described and figured in Vol. VI, of the Reports of the University Geological Survey of Kansas, now in press.

The author is aware that fossils, other than those mentioned in these lists, have been given for some of the horizons, but it is thought best in a work of this kind to give only those observed by him. With a few exceptions the fossils have been identified by the author, and most of them have been collected by him from the rocks *in situ.* The material in the Kansas University Museum, where there has been no doubt as to its stratigraphic position, has been used.

In the synonymy Weller, in his "Bibliographic Index of North American Carboniferous Invertebrate," Bulletin No. 153, U. S. Geol. Surv., has, for the most part, been followed. See Beede, Univ. Geol. Surv. of Kansas, Vol. VI (now in press), for departures from the synonymy given by Weller.

1. Bethany Falls Limestone. 78 Br. 38 Be. "18 to 20 feet heavy-bedded limestone." Kansas City, Mo.

Fusulina secalica Say.
Aulopora prosseri Beede.
Axophyllum rude White and St. John.
Lophophyllum profundum Milne-Edwards and Haime.
Archaeocidaris sp.
Fistulipora nodulifera Meek.
Pinnatopora trilineata Meek.
Pinnatopora sp.
Polypora sp.
Rhombopora sp.
Stenopora carbonaria Worthen.
Ambocoelia planoconvexa Shumard.
Chonetes vernenilanus Norwood and Pratten.
Hustedia mormoni Marcon.
Productus longispinus Sowerby. (c)[2]
Productus pertenuis Meek.
Productus semireticulatus Martin. (c)

1 This Journal, vol. ix, A, pp. 1-12. pls. i-ix (Jan. 1900).
2 (c) indicates that the fossil is common; (a) that it is abundant. When no letter is given, the fossil is only fairly common or rare.

Reticularia perplexa McChesney.
Spirifer cameratus Morton.
Spiriferina kentuckiensis Shumard.
Straparollus catilloides Conrad.

2. 79–82 Br. 37–28 Be.
"29th—2 inches of clay.
30th—3 inches of limestone.
31st—3 inches of buff shale.
32d—1 foot of buff clay rock.
33d—10 inches of yellow ochre shale.
34th—2 feet of drab shale.
35th—1⅓ feet of bituminous shale.
36th—3 feet of clay shale.
37th—2 feet of nodular buff shale."
Kansas City, Mo.
Fistulipora nodulifera Meek.
Rhombopora sp.
Septopora biserialis Swallow.
Orthothetes(?) sp.[1]
Productus longispinus Sowerby.
Seminula argentea Shepard.

3. 83–84 Br. 26–28 Be.
"26th—7½ feet heavy limestone, in two layers.
27th—10 inches blue shale.
28th—5 feet even-bedded limestone."
Kansas City, Mo.
Fenestella sp.
Fistulipora nodulifera Meek.
Pinnatopora multipora Rogers.
Polypora elliptica Rogers.
Stenopora carbonaria Worthen. (c)
Ambocoelia planoconvexa Shumard.
Chonetes vernenilanus N. and P.
Derbya sp.
Hustedia mormoni Marcon. (c)
Productus cora D'Orbigny. (c)
Productus costatus Sowerby.
Productus longispinus Sowerby. (c)
Productus pertenuis Meek. (a)

1 A small pedicle valve without a medium septum, is doubtfully referred to this genus. It might be considered as the young of *Derbya crassa* Meek and Hayden, had not Hall and Clarke figured the young of that species with a distinct medium septum. Nat. Hist. of N. Y., Paleontology vol. viii, pl. xi. B, f. 23,24.

Productus semireticulatus Martin.
Reticularia perplexa McChesney. (c)
Seminula argentea Shepherd. (c)
Spirifer cameratus Morton.
Spiriferina kentuckiensis Shumard.
Conocardium sp.
Bellerophon sp.
Capulus parvus Swallow.
Ostracod sp. (c)

4. Black cherty limestone. 85 Br. 24 Be.
"24th—12 feet deep-blue limestone and black chert in the upper 4 feet. From this down it is an argillaceous limestone and blue in lower strata."

Kansas City and Westport, Mo., Argentine, Kan.
Archæocidaris sp.
Spirorbis carbonaria Dawson.
Fenestella sp.
Polypora sp.
Septopora biserialis Swallow.
Derbya sp.
Lingula umbonata Cox.
Orbiculoidea sp.
Productus cora D'Orbigny.
Productus nebraskensis Owen.
Seminula argentea Shepherd. (c)
Allorisma subcuneatum Meek and Hayden.
Avicula longa Geinitz.
Aviculopecten carboniferus Stevens. (c)
Aviculopecten fasciculatus Keyes.
Aviculopecten occidentalis Shumard. (c)
Aviculopinna sp.
Lima retifera Shumard.
Monopteria longispina Cox.
Myalina ampla Meek.
Nucula ventricosa Hall.
Pseudomonotis tenuistriatus Beede.
Schizodus wheeleri Swallow. (c)
Schizodus sp.
Sedgwickia topekensis Shumard.
Solenomya parallela Beede and Rogers.
Solenomya trapezoides Meek. (c)
Bellerophon crassus Meek and Worthen. (c)

Bellerophon percarinatus Conrad. (c)
Naticopsis sp.
Pleurotomaria broadheadi White.
Pleurotomaria tabulata Conrad.
Straparollus sp.
Asymptoceras capox M. and W.
Coloceras globatus Meek and Worthen.
Cyrtoceras sp.
Domatoceras lasallensis M. and W.
Ephippioceras ferratus Cox.
Goniatites sp.
Metacoceras sangamonensis M. and W.
Nantilus planorbiformis M. and W.
Nantilus planovolvis Shumard.
Orthoceras rushense McChesney.
Tainoceras occidentalis Swallow.
Titanoceras ponderosum Meek.
Phillipsia major Shumard.
Fish tooth.

5. Alternating shales and limestones. 86 Br. 17–23 Be.
"17th—13 feet shale.
18th—1 foot argillaceous limestone, made of comminuted shells.
19th—10 inches drab clay shales.
20th—5 inches argillaceous limestone.
21st—2 feet drab clay shales; 6 inches buff shales, and 6 inches blue shales.
22d—1 foot argillaceous limestone.
23d—1 foot buff and 3 feet of blue shales."
Kansas City, Mo.
Rhombopora sp. (c)
Andcoelia planoconvexa Shumard. (a)
Chonetes vernenilanus N. and P. (a)
Productus longispinus Sowerby. (c)
Seminula argentea Shepherd. (c)

6. Oōlitic limestone. 87a Br. 16 Be.
"16th—18 feet oōlitic and gray limestone."
Rosedale, Argentine, Turner, Kansas, and Kansas City, Mo.
Fenestella perelegans Meek.[1]
Fistulipora nodulifera Meek (c)
Polypora elliptica Rogers.

1 This is the fossil usually referred to Fenestella Shumard's Pront. See Nickles & Bassler, Bull. U. S. Geol. Surv. No. 173. "Synopsis of American Fossil Bryozoa."

Polypora sp.
Septopora biserialis Swallow. (c)
Stenopora carbonaria Worthen. (c)
Derbya sp.
Dielasma bovidens Morton. (c)
Hustedia mormoni Marcon. (c)
Productus nebraskensis Owen. (c)
Productus semireticulatus Martin. (c)
Semenula argentea Shepherd. (c)
Spirifer cameratus Morton. (c)
Spiriferina kentuckiensis Shumard. (c)
Allorisma costatum M. and W.
Avicula sulcata Geinitz.
Aviculopecten carboniferus Stevens.
Aviculopecten fasciculatus Keyes.
Aviculopecten neccoyi M. and H.
Aviculopecten occidentalis Shumard. (c)
Cypricardinia carbonaria Meek. (c)
Edmondia nebraskensis Geinitz.
Lima retifera Shumard.
Macrodon obsoletus Meek.
Macrodon sp.
Modiola subelliptica Meek.
Monopteria alata Beede.
Monopteria gibbosa M. and W.
Monopteria longispina Cox.
Monopteria marian White.
Myalina kansasensis Shumard.
Myalina subquadrata Shumard.
Myalina swallovi McChesney. (c)
Nucula ventricosa Hall. (c)
Nuculana bellistriata attenuata Meek. (c)
Pinna sp.
Pleurophorus subcostatus M. and W.
Pleurophorus tropidophorus Meek.
Pseudomonotis hawni M. and H. (c)
Pseudomonotis cf. hawni. (c)
Pseudomonotis equistriata Beede. (c)
Pseudomonotis robusta Beede. (c)
Pseudomonotis tenuistriata Beede. (c)
Streblopteria tenuilineatus(?) M. and W.
Bellerophon bellus Keyes. (c)

Bellcrophon marconanus Geinitz. (c)
Strophostylus nana M. and W.
Ephippoceras ferratus Cox.
Metacoceras sangamonensis M. and W.
Nautilus planuvolvis Shumard.
Orthoceras sp.
Titanoceras ponderosum Meek.
Phillipsia major Shumard.
Phillipsia nodacostatus Hare.

7. Shales and limestones. 88–89 Br. 14–15 Be.
"14th—7 feet clay shales.
15th—3 feet irregularly-bedded limestone."
No fossils from these horizons were found.

8. Campophyllum limestone. 90 Br. 13 Be.
"13th—9 feet fine-grained, greenish gray, even-bedded limestone."

Kansas City and Wesport, Mo.
Axophyllum rude White and St. John.
Campophyllum torquium Owen. (a)
Lophophyllum sp.
Michelinia eugeneae White.
Cromyocrinus sangamonensis M. and W.
Cyathocrinus stillativus White.
Hydreionocrinus pentagonus Miller and Gurley.
Hydreionocrinus sp.
Acanthocladia pinnata Rogers.
Chainodicyton laxum Foerste.
Cystodictya inequimarginata Rogers.
Fenestella limbata Foerste.
Fenestella sp.
Fistulipora nodulifera Meek.
Pinnatopora sp.
Polypora elliptica Rogers.
Polypora submarginata Meek.
Polypora sp.
Rhombocladia delicata Rogers.
Rhombopora lepidodendroidea Meek.
Rhombopora sp.
Septopora biserialis Swallow.
Stenopora carbonaria Worthen.
Chonetes vernenilanus N. and P.
Cleiothyris roisyii L' Eveille.

Derbya crassa M. and H. (c)
Hustedia mormoni Marcou.
Productus longispinus Sowerby. (c)
Productus nebraskensis Owen. (c)
Productus punctatus Martin.
Productus semireticulatus Martin.
Seminula argentea Shepherd. (c)
Spirifer cameratus Morton. (c)
Spiriferina kentuckiensis Shumard.
Reticularia perplexa McChesney.
Aviculopecten occidentalis Shumard.
Myalina kansasensis Shumard.
Myalina subquadrata Shumard.
Capulus parvus Swallow.
Pleurotomaria missouriensis Swallow. (c)
Gasteropod sp.
Phillipsia major Shumard.
Fish tooth.

9. Shales and limestones. 91–95 Br. 6–12 Be
"6th—Thin seam of clay, 4 inches.
7th—15 inches blue limestone.
8th—2 feet bituminous and blue clay shales.
9th—18 inches in one bed of limestone.
10th—16 inches blue clay shales.
11th—16 inches blue limestone, largely composed of comminuted shells.
12th—11 feet: 5 feet 8 inches blue clay shales and 5 feet 4 inches buff and drab nodular shales."
Kansas City, Mo.
Fusulina secalica Say.
Lophophyllum profundum Milne-Edwards and Haime.
Cystodictya inequimarginata Rogers.
Fenestella limbata Foerste.
Pinnatopora sp.
Polypora elliptica Rogers.
Rhombopora lepidodendroides Meek. (c)
Rhombopora sp.
Septopora biserialis Swallow. (c)
Septopora interporata(?) Rogers.
Chonetes vernenilanus N. and P.
Derbya crassa M. and H.

Derbya keokuk Hall.[1]
Hustedia mormoni Marcou.
Productus cora D'Orbigny.
Productus longispinus Sowerby.
Productus nebraskensis Owen.
Productus punctatus Martin.
Pugnax uta Marcou.
Rhipidomella pecosi Marcou.
Seminula argentea Shepherd.
Spirifer cameratus Morton.
Spiriferina kentuckiensis Shumard.
Aviculopecten carboniferus Stevens.
Aviculopecten occidentalis Shumard.
Aviculopecten rectalaterarius Cox.
Lima retifera Shumard.
Myalina swallovi McChesney.
Schizodus sp.
Gasteropod sp.
Conularia crustula White. (c)
Goniatites sp.
Nautilus sp.
Orthoceras sp.
Phillipsia major.
Listiacanthus hystrix. (c)
Fish tooth.
Crucipes parva Butts.
Duovestigia scala Butts.
Notalacerta jacksonensis Butts.
Notalacerta missouriensis Butts.
Notamphibia magna Butts.
Punctatumvestigium circuliformis Butts.

10. Heavy-bedded limestone. 96 Br. 5 Be.
"5th—5 feet heavy-bedded limestone.
Kansas City, Mo.
Axophyllum rude White and St. John.
Campophyllum torquium Owen.
Lophophyllum profundum Milne-Edwards and Haime.
Lophophyllum westii Beede.[2]
Archaeocidaris sp.

1 *Derbya keokuk* Hall, and *D. robusta* Hall are synonyms. See Beede. Univ. Geol Surv. Kan., vol. vi.
2 This is the fossil usually called *Cyathaxonia distorta*.

Cystodictya inequimarginata Rogers.
Fenestella kansasensis Rogers.
Fenestella perelegans Meek.
Fistulipora nodulifera Meek.
Pinnatopora sp.
Polypora elliptica Rogers.
Polypora triangularis Rogers.
Rhombocladia delicata Rogers.
Rhombopora sp.
Septopora biserialis Swallow.
Septopora interporata(?) Rogers.
Stenopora sp.
Ambocoelia planoconvexa Shumard.
Chonetes vernenilanus N. and P.
Derbya sp.
Diclasma bovideus Morton.
Hustedia mormoni Marcou.
Meekella striatocostata Cox.
Productus cora D'Orbigny. (c)
Productus costatus Sowerby. (c)
Productus longispinus Sowerby.
Productus nebraskensis Owen. (c)
Productus punctatus Martin. (c)
Productus semireticulatus Martin. (c)
Rhipidomella pecosi Marcou. (c)
Seminula argentea Shepherd. (c)
Spirifer cameratus Morton. (c)
Spiriferina kentuckiensis Shumard.
Aviculopecten interlineatas M. and W.
Chaenomya sp.
Pinna sp.
Ostracod sp.

11. Shale. 97 Br. 4 Be.
"4th—25 feet blue and olive-colored shales."
Kansas City, Mo., and Argentine, Kans.
Ceriocrinus hemisphericus Shumard. (c)
Ceriocrinus missouriensis Miller and Gurley.
Ceriocrinus nodulifera Butts.[1]
Erisocrinus toddanus Butts.[1]
Erisocrinus typus M. and W. (c)

1 Butts. Trans. Acad. of Sci. of Kansas City, vol. 1. pp. 13-15. Plate. 1899.

Eupachycrinus harii Miller.
Eupachycrinus magister M. and G.
Eupachycrinus sphaeralis M. and G.
Phialocrinus basilicus M. and G.
Phialocrinus barydactylus Keyes.
Phialocrinus harii M. and G.
Phialocrinus lykinsi Butts.
Phialocrinus magnificus M. and G. (c)
Fistulipora nodulifera Meek.
Polypora sp.
Rhombopora lepidodendroidea Meek.
Septopora biserialis Swallow.
Stenopora ohioensis Foerste.
Stenopora spinulosa Rogers.
Derbya crassa M. and H.
Lingula umbonata Cox.
Orbiculoidea convexa Shumard.
Productus nebraskensis Owen. (c)
Productus pertenuis Meek.
Productus symmetricus McChesney.
Seminula argentea Shepherd. (c)
Avicula longa Geinitz
Aviculopecten occidentalis Shumard. (c)
Aviculopinna americanum
Aviculopinna illinoisensis.
Edmondia nebraskensis Geinitz.
Lima retifera Shumard.
Modiola subelliptica Meek.
Monopteria gibbosa M. and W.
Myalina swallovi McChesney. (c)
Myalina sp.
Nuculana bellistriata Stevens.
Schizodus harii Miller. (c)
Schizodus sp. cf. affinis Herrick.
Streblopteria termilineatus(?) M. and W.
Yoldia cf. knoxensis McChesney.
Bellerophon carbonarius Cox
Bellerophon carbonarius Conrad. (c)
Dentalium meekianum Geinitz.
Pleurtomaria missouriensis Swallow.
Pleurtomaria sp.
Conularia crustula White.

Orthoceras sp.
Nautilus sp.
Tainoceras occidentalis Swallow.

12. Iola limestone. 98 Br. 3 Be.
"3d—30 feet of gray, bluish gray and flesh-colored limestone, the Iola limestone."

Sponge sp.
Axophyllum rude White and St. John.
Lophophyllum profundum Milne-Edwards and Haime.
Lophophyllum westii Beede.
Michelinia eugeneae White.
Syringopora(?) n. sp.
Ceriocrinus hemisphericus Shumard.
Archaeocidaris triserrata(?) Meek.
Spirorbis carbonarius Dawson.
Chainodictyon laxum Foerste. (c)
Cystodictya divisa Rogers.
Cystodictya inequimarginata Rogers. (c)
Fenestella kansasensis Rogers.
Fenestella limbata Foerste. (c)
Fenestella ovatipora Rogers.
Fenestella remota Foerste. (c)
Fenestella perelegans Meek.
Fistulipora nodulifera Meek. (c)
Pinnatopora pyriformipora Rogers.
Pinnatopora trilineata Meek.
Pinnatopora whitii Foerste.
Polypora elliptica Rogers.
Polypora flexuosa Rogers.
Polypora submarginata Meek.
Polypora triangularis Rogers.
Rhabdomeson americanum Rogers.[1]
Rhombocladia delicata Rogers.
Rhombopora lepidodendroidea Meek. (c)
Septopora biserialis Swallow.
Septopora interporata Rogers.
Stenopora carbonaria Worthen.
Streblotrypa striatopora Rogers.
Thamniscus tenuiramus Rogers.
Ambocoelia planoconvexa Shumard.

1 Described in the preceding number of this Journal.

Chonetes vernenilanus N. and P.
Cleiothyris roisyii L' Eveille.
Crania modesta White and St. John.
Derbya bennetti(?) Hall and Clarke.
Derbya keokuk(?) Hall.
Derbya sp.
Diclasma bovidens Morton.
Hustedia mormoni Marcou.
Orbiculoidea convexa Shumard.
Orbiculoidea missouriensis Shumard.
Productus cora D'Orbigny. (c)
Productus longispinus Sowerby. (a)
Productus nebraskensis Owen. (c)
Productus pertenuis Meek. (c)
Productus punctatus Martin. (c)
Productus semireticulatus Martin. (c)
Pugnax uta Marcou.
Reticularia perplexa McChesney.
Spirifer cameratus Morton.
Spiriferina kentuckiensis Shumard. (c)
Allorisma costatum M. and W.
Allorisma granosum Shumard.
Allorisma subcuneatam M. and H.
Avicula sulcata Geinitz.
Aviculopecten carboniferus Stevens. (c)
Aviculopecten interlineatus M. and W.
Aviculopecten mccoyi M. and H.
Aviculopecten occidentalis Shumard.
Conocardium parrishi(?) Worthen.
Cypricardinia carbonaria(?) Meek.
Edmondia sp.
Lima retifera. Shumard.
Macrodon sp.
Myalina kansasensis Shumard.
Pernopecten aviculatus(?) Swallow.
Pinna sp.
Gasteropod sp.
Orthoceras sp.
Nautilus sp.
Ostracods, several species.
Cyclus n. sp.
Phillipsia major Swallow.

Peripristis semicircularis Newberry and Worthen.

13. Under this heading are given all the strata included between the Iola Limestone and the Lower Garnett Limestone. In the absence of detailed stratigraphic work it can not be said whether they are persistent or merely local systems. They are accordingly grouped together and the fossils occuring in the two limestones are given in the same list.

Argentine, Kansas.

33 feet covered slope containing shale [1]

3 feet limestone.

7½ feet shale.

10½ feet limestone, oölitic in part.

7½ feet shale.

Archæocidaris sp.

Festulipora nodulifera Meek.

Rombopora sp. (c)

Septopora biserialis Swallow.

Productus cora D'Orbigny.

Productus nebraskensis Owen.

Productus semireticulatus Martin.

Seminula argentea Shepherd. (c)

Spirifer cameratus Morton.

Aviculopecten occidentalis Swallow.

Myalina subquadrata Shumard. (c)

Penna sp.

Phillipsia major Shumard.

14. Lower Garnett Limestone.

Eudora, Douglas county, Kansas.

6 feet thick.

Fusulina secalica Say.

Lophophyllum profundum M.-E. and H.

Archæocidaris sp.

Serpula insita White.

Fenestella limbata Foerste.

Fenestella remota Foerste.

Fistulipora sp.

Pinnatopora multipora Rogers.

Pinnatopora trilineata Meek. (c)

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1 The limestone capping the top of the hills at Argentine is the Lower Garnett. Many species which occur in that limestone at Eudora, Kansas, are found here, including *Euteletes hemiplicata*. Bennett not finding this fossil in the limestone at the top of the hill concluded that the Lower Garnett (Syntriclasma) limestone was contained in the covered slope. See Univ. Geol. Surv. Kans., vol. I, pp. 111-112, 1896.

Polypora sp.
Polypora sp.
Rhombocladia delicata Rogers.
Chronetes vernenilanus N. and P.
Crania modesta White and St. John.
Derbya sp.
Diclasma bovidens Morton. (c)
Euteletes hemiplicata Hall. (a)
Productus cora D'Orbigny, (c)
Productus cora americana Swallow.
Productus longispinus Sowerby. (c)
Productus nebraskensis Owen.
Productus pertenuis Meek. (c)
Productus punctatus Martin.
Seminula argentea Shepherd. (c)
Spirifer cameratus Morton.
Spiriferina kentuckiensis Shumard.
Aviculopecten carboniferus Stevens. (c)
Aviculopecten occidentalis Shumard.
Conocardium sp.
Myalina sp.
Pelycepod sp.
Pelycepod sp.
Pelycepod sp.
Pleurotomaria missouriensis Swallow.
Gasteropod sp.
Gasteropod sp.
Gasteropod sp.
Gasteropod sp.
Griffithides scitula M. and W.
Cyclus n. sp.
Ostracod sp.
Ostracod sp.

15. Upper Garnett Limestone.

". . . 12 feet thick at Eudora, ... above it 3 feet of brown and somewhat calcified clay shales, upon which lies 1½ feet of thinly laminated limestone."[1]

Eudora, Douglas county, Kansas.
Fusulina secalica Say.
Archæocidaris sp.
Fenestella limbata Foerste.

1 Bennett. Univ. Geol. Surv. Kans., vol. 1, p. 113, 1896.

Fistulipora nodulifera Meek.
Pinnatopora trilineata Meek.
Rhombopora lepidodendroidea Meek.
Septopora biserialis Swallow.
Chonetes granulifer Owen.
Meekella striatacostata Cox.
Orthothetes(?) sp.
Productus pertenuis Meek.
Productus semireticulatus Martin.
Rhipidomella pecosi Marcou.
Seminula argentea Shepherd.
Spirifer cameratus Morton.
Spiriferina kentuckiensis Shumard.
Aviculopecten occidentalis Shumard.

16. Lawrence Oölite.

Oölitic limestone at top grading into calcareous sandstone at the bottom, about 6 feet thick. Located within the Lawrence Shales. A local horizon very prolific in animal remains.

Dam at Lawrence, Kansas, and at Cameron's Bluff, three miles west of Lawrence.

Fusulina secalica Say.
Lophophyllum sp.
Hydreionocrinus subsinuatus(?) M. and G.
Archæocidaris sp.
Fenestella shumardi(?) Prout.
Pinnatopora sp.
Polypora sp.
Polypora sp.
Rhombopora sp.
Septopora biserialis Swallow.
Aulacorhynchus millepunctatus M. and W.
Chonetes granulifer Owen.
Chonetes vernenilanus N. and P.
Derbya keokuk Hall.
Derbya sp.
Diclasma bovidus Morton.
Meekella strictocostata Cox.
Orbiculoidea missouriensis Shumard.
Orbiculoidea sp.
Productus cora D'Orbigny. (c)
Productus longispinus Sowerby.
Productus nebraskensis Owen. (c)

Productus pertenuis Meek. (c)
Productus punctatus Martin.
Productus semireticulatus Martin.
Pugnax eta Marcou.
Reticularia perplexa McChesney.
Semiaula argentea Shepherd. (c)
Spirifer cameratus Morton.
Avicula longa Geinitz. (c)
Avicula sulcata Geinitz (c)
Aviculopecten carboniferus Stevens.
Aviculopecten germanus(?) Miller and Faber.
Aviculopecten mccoyi M. and H.
Aviculopecten occidentalis Shumard. (c)
Aviculopecten sculptilis Miller.
Chaenomya leavenworthensis M. and H.
Cypricardinia carbonaria Meek.
Edmondia nebraskensis Geinitz. (c)
Lima retifera.
Macrodon obsoletus Meek.
Macrodon sangamonenensis Worthen.
Modiola subelliptica Meek.
Monopteria alata Beede.
Monopteria gibbosa M. and W.
Monopteria longispina Cox. (c)
Monopteria marion White. (c)
Monopteria subalata Beede and Rogers.
Myalina subquadrata Shumard. (c)
Myalina swallovi McChesney. (c)
Myalina sp.
Nucula pulchella Beede and Rogers.
Nuculana bellistriata Stevens.
Pernopecten aviculatus(?) Swallow.
Pinna sp.
Pleurophorus subcostatus M. and W.
Posidonomya(?) *pertenuis* Beede.
Posidonomya(?) *recurva* Beede.
Posidonomya sp.
Prothyris elegans(?) Meek.
Pseudomonotis hawni M. and H. (c)
Pseudomonotis cf. hawni.
Pseudomonotis tenuistriata Beede.
Schizodus compressus Rogers. (c)

Schizodus subcircularis Herrick.
Schizodus sp.
Solenomya parallela Beede and Rogers.
Yoldia glabra Beede and Rogers.
Bellerophon bellus(?) Keyes.
Bellerophon carbonarius Cox.
Bellerophon crassus M. and W.
Bellerophon marcouanus Geinitz.
Naticopsis altonensis McChesney.
Pleurotomaria missouriensis Swallow.
Gasteropod sp.
Gasteropod sp.
Cyrtoceras sp.
Metacoceras sangamonensis M. and W.
Nautilus planovolvis Shumard.
Tainoceras occidentalis Swallow.
Griffithides scitula M. and W.
Crustacean sp.
Ostracod sp.
Fish tooth.

17. Lower Oread Limestone.
About 12 feet thick.
Lawrence, Kansas.
Fusulina secalica Say. (c)
Aulopora prosseri Beede.
Axophyllum rude White and St. John.
Lophophyllum profundum M.-E and H. (c)
Lophophyllum westii Beede.
Ceriocrinus hemisphericus.
Hydreionocrinus(?) sp.
Archæcidaris sp.
Cystodictya inequimarginata Rogers.
Fenestella kansasensis Rogers.
Fenestella limbata Foerste.
Fenestella remota Foerste.
Fenestella perelegans Meek.
Fistulipora nodulifera Meek. (c)
Pinnatopora ptiloporoidea Rogers.
Pinnatopora trilineata Meek.
Pinnatopora whitii Foerste.
Pinnatopora sp.
Polypora elliptica Rogers.

Polypora flexuosa(?) Rogers.
Polypora missouriensis(?) Rogers.
Polypora spinulifera(?) Ulrich.
Polypora submarginata Meek.
Polypora triangularis Rogers.
Rhabdomeson americanum Rogers.[1]
Rhombocladia delicata Rogers.
Rhombopora lepidodendroidea Meek.
Septopora biserialis Swallow.
Streblotrypa prisca Gabb and Horn.
Streblotrypa striatoporà Rogers.
Thamniscus tenuiramus(?) Rogers.
Bryozoan n. gen.
Ambocoelia planuconvexa Shumard. (c)
Chonetes granulifer Owen. (c)
Derbya bennetti Hall and Clarke.
Derbya crassa M. and H.
Derbya keokuk Hall.
Enteletes hemiplicata Hall.
Hustedia mormoni Marcou.
Meekella striatocostata Cox. (c)
Productus cora D'Orbigny. (c)
Productus costatus Sowerby.
Productus longispinus Sowerby. (c)
Productus punctatus Martin.
Productus semireticulatus Martin. (c)
Reticularia perplexa McChesney. (c)
Rhipidomella pecosi Marcou. (c)
Seminula argentea Shepherd. (c)
Spirifer cameratus Morton. (c)
Spiriferina kentuckiensis Shumard. (c)
Allorisma granosum Shumard.
Allorisma subcuneatum M. and H.
Aviculopecten germanus(?) Miller and Faber.
Aviculopecten occidentalis Shumard.
Myalina sp.
Nuculana bellistriata Stevens.
Pinna sp.
Naticopsis sp.
Gasteropod sp.
Domatoceras lasallensis(?) M. and W.

1 This species is described in the preceding (July) number of this journal.

Ephippoceras ferratus Cox.
Tainoceras occidentalis Swallow.
Griffithides scitula M. and W.
Fish tooth.

18. Oread Shales.

"425 feet bituminous shale, between the Lower and Upper Oread Limestones.

Lecompton, Kanas.
Ambocoelia planoconvexa Shumard. (c)
Crania modesta White and St. John.
Orbiculoidea missouriensis Shumard. (c)
Productus cora D'Orbigny. (a)
Pugnax uta Marcou. (c)
Seminula argentea Shepherd. (c)
Aviculopecten coxanus M. and W.
Posidonomya sp.
Pleurotomaria sp.
Insect wing.

19. Upper Oread Limestone.

"22½ feet thick, capable of subdivision as follows: Resting at its base are a few feet of bituminous shales, then 12 feet of heavy-bedded rock, the middle two feet of which is very cherty. Above this lies 1 foot of blue clay shales; then 6 feet of shelly nodular limestone with heavy clay partings abounding in well preserved fossils, and this again capped by an even stratum 1½ feet thick, separated from two layers above by 4 inches of clay, the top layer being 1¾ feet thick."[1]

Lecompton, Douglas county, Kansas.
Fusulina secalica Say. (a)
Aulopora prosseri Beede. (c)
Camphophyllum torquium Owen.
Lophophyllum westii Beede.
Cystodictya inequimarginata Rogers.
Fenestella remota Foerste.
Fenestella sp.
Fistulipora nodulifera Meek. (a)
Pinnatopora sp.
Polypora elliptica Rogers. (c)
Polypora triangularis Rogers. (c)
Polypora sp.

1 Bennett. Univ. Geol. Surv. Kans., vol. 1, p. 115, 1896.

Rhombopora lepidodendroidea Meek. (c)
Rhombopora sp. (c)
Septopora biserialis Swallow.
Streblotrypa prisca Gabb and Horn.
Streblotrypa striatopora Rogers.
Ambocoelia planoconvexa Shumard. (c)
Chonetes granulifer Owen. (c)
Derbya bennett Hall and Clarke. (c)
Derbya keokuk Hall. (c)
Diclasma bovidens Morton.
Enteletes hemiplicata Hall. (c)
Hustedia mormoni Marcou. (c)
Meekella striatocostata Cox.
Productus cora D'Orbigny. (a)
Productus costatus Sowerby.
Productus longispinus Sowerby.
Productus nebraskensis Owen.
Productus pertenuis Meek.
Productus punctatus Martin.
Productus semireticulatus Martin.
Pugnax uta Marcou.
Rhipidomella pecosi Marcou. (c)
Seminula argentea Shepherd. (c)
Spirifer cameratus Morton. (c)
Spiriferina kentuckiensis Shumard. (c)
Allorisma granosum Shumard.
Allorisma subcuneatum M. and H.
Aviculopecten carboniferus Stevens.
Aviculopecten mccoyi M. and H.
Aviculopecten providencesis Cox.
Chaenomya cooperi(?) M. and H.
Edmondia sp.
Lima retifera Shumard.
Monopteria marian White.
Myalina sp.
Pinna peracuta Shumard.
Pleurophorus sp.
Schizodus wheeleri Swallow.
Bellerophon crassus M. and W. (c)
Bellerophon sp.
Euomphalus sp.
Naticopsis sp.
Gasteropod sp.
Griffithides scitula M. and W.

Microscopic Comparison of Samples of White Arsenic.

BY EDWARD BARTOW.

With Plates XLVI, XLVII and XLVIII.

In a recent case of suspected poisoning in this state,[1] a bottle of malted milk was brought to me for examination I found evidence of the presence of arsenic by the Marsh test, and by the Reinsch test; and even the simple test of heating the substance with a piece of charcoal, in a glass tube closed at one end, gave a heavy arsenic mirror.

Considering the greasy nature of the material under examination, I conceived the idea of separating the crystals of white arsenic, if the arsenic should be present in that form, by means of ether. On panning the malted milk with ether in a shallow porcelain dish, I was enabled to separate quantities of the crystals in a pure state. An attempt to do this with water failed. In fact water could not be used on them until they were free from the fat.

A few crystals of white arsenic were separated from a bottle of whiskey found on the premises of the deceased.

In following up a clue that seemed to point to the source from which the poison might have been obtained, the county attorney submitted to me a sample of white arsenic crystals obtained from this source. He requested me to determine whether they were like those found in the malted milk or in the whiskey. To my knowledge, the only work of such a nature is that of Professor E. S. Dana.[2] Professor Dana enters into an exhaustive account of the methods of preparing white arsenic, and of the possibilities of differences due to the variations of the conditions during the process. He also made microscopical examinations of many samples of commercial arsenic, and deduced the following conclusions: "The study of a large number of independent samples of commercial white arsenic confirms the conclusions based upon the observations as to the method of manufacture, and shows that wide

1 State of Kansas vs. Kunkel.
2 Microscopic Examination of Samples of Commercial Arsenic, Jersey City, 1880.

variations in character often exists. These differences, when they occur, are readily distinguishable by the microscope, and, in most every case, it is, by this means, possible to conclude, of two test samples, whether they *could* or *could not* have come from the same source; and this is true, under favorable conditions, even if one of the samples has been subjected, for some time, to the action of the stomach."

The work of Professor Dana is well known, but at first I had only at command the limited notice given to it in the works on toxicology. Later I received the article of Professor Dana, which he kindly sent me, and was interested in carrying out more in detail the methods of work which he describes. My method of work follows:

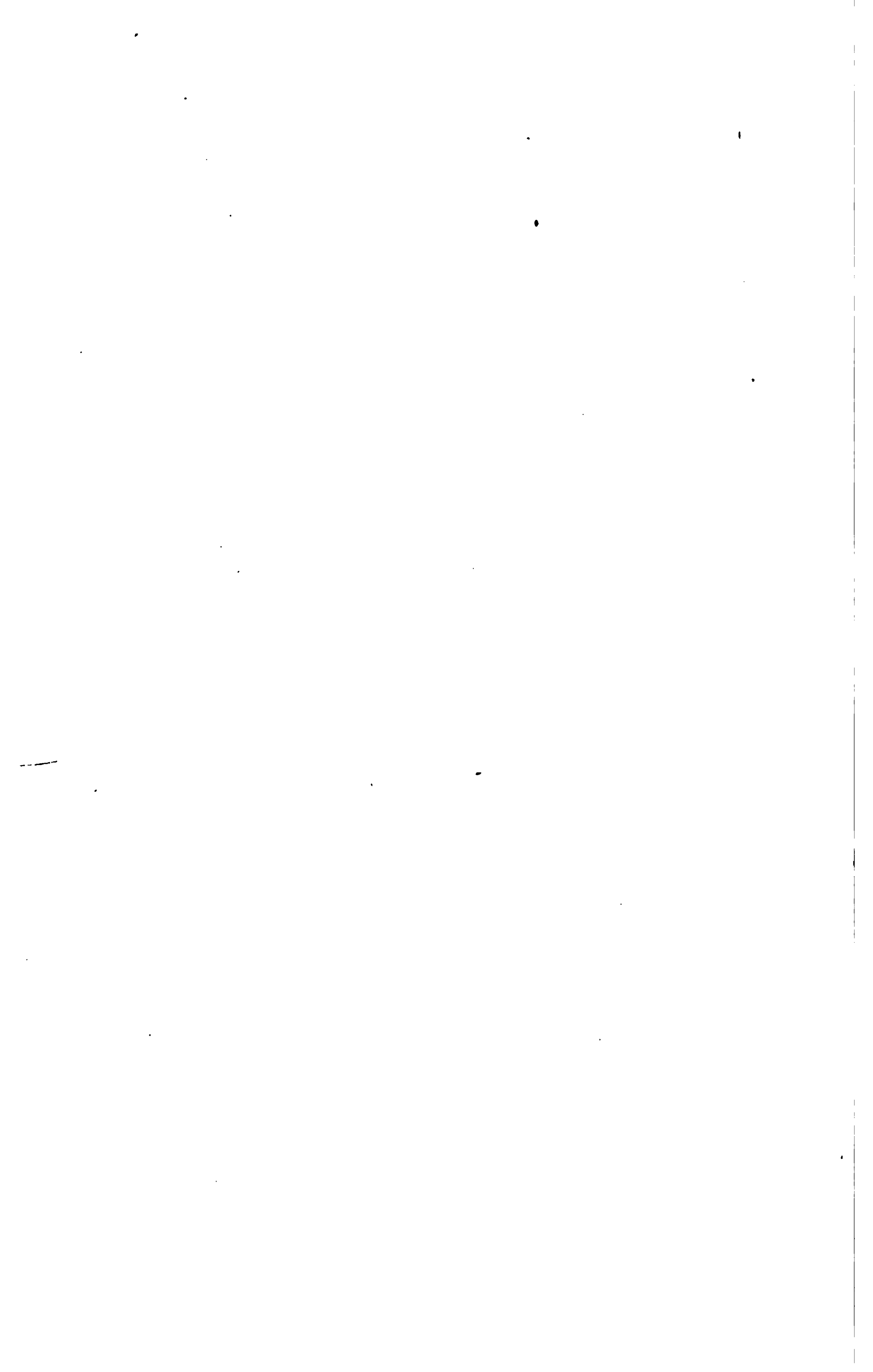
I mounted a few slides of each of the samples (the limited amount of crystals separated from the whiskey made but one slide) as well as samples of white arsenic from the laboratories of the university and from the drug stores of the city. Differences were so marked that I at once concluded that the sample submitted by the county attorney and the arsenic from the malted milk could not have had the same source. To assure myself that the treatment with ether had not changed the character of the crystals from the malted milk, I mixed some of the arsenic from the suspected source with pure malted milk, using the same proportions as were found in the malted milk containing the poison, then panned out the arsenic in the same manner as from the original sample of malted milk. Several slides were made with the arsenic treated in this way. After the process there was no difference in the appearance of the sample.

In the microscopical examination, I noted the size of the crystals, the size of the amorphous bodies present, the character of the amorphous bodies, and the relative number of crystals and amorphous bodies. We may thus summarize the observations of the crystals from the milk (Fig. 4), the whiskey (Fig. 3), and the suspected sample (Figs. 1 and 2). The crystals from the suspected sample were the smallest, those from the whiskey were the largest, though not much larger than those from the malted milk. The amorphous bodies were of a similar size in each sample. In each case were some much larger than the crystalline bodies. Those from the milk were of a transparent nature, while the others were opaque. In the suspected sample, about 25 per cent were well shaped crystals. In the sample from the whiskey about 15 per cent were crystals. That from the malted milk showed about

40 per cent of crystals. From these differences I concluded that the arsenic in the suspected sample could not have had the same source as that found in the milk and the whiskey.

In order to be sure that my separation of the various slides into groups was not due to my familiarity with them, I submitted these slides, together with slides prepared from arsenic from other sources, to Professor S. W. Williston, to Professor W. C. Stevens, and to Professor E. Haworth. Each had no difficulty in separating the slides submitted into groups, always putting those from the same source into the same group, and never classifying the suspected sample with the specimens from the milk and the whiskey, thus confirming my own conclusions.

All the comparisons were made directly from the slides, and, in fact, a better judgment can be formed by observing a considerable portion of each slide. I have, however, had a number of microphotographs made by Mr. F. E. Marcy the university photographer. These show the crystals magnified seventy-five diameters and give a very good illustration of the variations in the various samples. I have added also photographs of samples from specimens of white arsenic in the chemistry (Fig. 5) and pharmacy laboratories (Fig. 6) of the university, because they show a great variation in the percentage of crystals, though the particles are nearly of the same size.



The Detection of Arsenic, Antimony and Tin.

BY HAMILTON P. CADY.

The detection of arsenic, antimony and tin in the presence of one another is a rather long and tedious process when carried out by the ordinary qualitative methods. The Marsh test, either in its original form or with the silver nitrate modification, is probably the best of the common methods, but even this is not very successful in the hands of many students. The following method has been found rapid and convenient:

The process is carried out as follows: three or four c. c. of the solution to be tested is placed in a test tube, and about one and one-half times the volume of concentrated hydrochloric acid is then added, and hydrogen sulfid passed through the solution. The arsenic, whether in the arsenous or arsenic condition, is precipitated as $As_2 S_3$, while the antimony and tin remain in solution. If the arsenic is in the arsenous condition, the precipitate will settle out, leaving the solution clear; while if it is in the arsenic condition, the sulfur formed during its reduction will remain suspended, rendering the liquid turbid. So one can not only detect the arsenic, but can also tell whether it is arsenous or arsenic. If arsenic acid is formed it will, of course, be necessary to test for arsenous some other way.

After the arsenic has been precipitated the tube is inclined at an angle of about thirty degrees, and cold water saturated with hydrogen sulfid is carefully poured in, stirring up the solution as little as possible. Almost as soon as the first drops of water touch the solution the antimony sulfid is precipitated as an orange red ring or layer floating on the highly acid solution. Upon further dilution the yellow stannic sulfid is precipitated and blending into this the brown to black stannous sulfid. After standing a few moments there will be a marked line of demarkation between the antimony and tin. A tube containing these substances, when treated in this way, presents a very striking appearance with its several highly colored layers.

Since arsenic acid and stannous salts react upon each other, of course these two can not exist in the same solution.

The chemistry of this is simple. Arsenic, in arsenous condition, has but little tendency to form positive ions, and the chlorid, even in as strongly acid solution as the one used, is completely hydrolized to arsenous acid. Since this is a weak acid in the presence of such strong hydrochloric acid, it will exist, practically all, as the undissociated acid H_3AsO_3. Hydrogen sulfid acts upon this, the sulfur and oxygen exchanging places. Hydrogen ions accelerate this, and the stronger the acid the faster it goes, indicating that it is the undissociated hydrogen sulfid acting upon the undissociated arsenous acid and not an action between the ions.

The reaction is as follows:

$$H_3AsO_3+3H_2S+H^++Cl^-=H_3AsS_3+3H_2O+H^++Cl^-$$

$$2H_3AsS_3=As_2S_3+3H_2S.$$

The concentration of hydrochloric acid being the same on both sides of the equation, the arsenous sulfid should be, and is, just as insoluble in concentrated as in dilute hydrochloric acid.

Antimony and tin readily form positive ions, and the reaction for the formation of these sulfids is between their ions and the sulfur ions form the hydrogen sulfid. Hydrogen sulfid is a very weak acid and breaks up into this

$$\underset{C_1}{H_2S}=\underset{C_2}{2H^+}+\underset{C_3}{S^=}$$

and according to the Mass Law,

$$K=\frac{C_2^2C_3}{C_1}$$

and hence if the concentration of H^+ be increased by adding hydrochloric acid or any strong acid the concentration of sulfur as ion must decrease; and the greater the concentration of the hydrogen as ion, the less that of sulfur, and since the product of the concentration of antimony as ion and sulfur as ion must reach a certain value before antimony sulfid can be precipitated, it follows at once that it is only necessary to make the solution highly acid in order to prevent the antimony coming down with the arsenic.

The chlorine as ion from the hydrochloric acid decreases the dissociation of the antimony chlorid and this also tends to increase the solubility of the antimony sulfid.

For exactly the same reasons, the sulfids of tin may be hindered from precipitating by making the solution highly acid. Hydrochloric acid of the concentration indicated is sufficiently strong to entirely prevent the precipitation of antimony or tin while the arsenic is promptly thrown. On account of its slight degree of dissociation, hydrogen sulfid is practically as soluble in hydrochloric acid as in water, and therefore in diluting the solution with water saturated with hydrogen sulfid, the concentration of the hydrogen sulfid can be treated as a constant, and from the equation

$$\underset{C_1}{H_2S} = \underset{C_2}{2H^+} + \underset{C_3}{S^=}$$

$$KC_1 = C_2^2 C_3 \text{ or since } C_1 = \text{const.}$$

$$K^1 = KC^1 = C_2^2 C_3$$

$$\frac{K^1}{C_2^2} = C_3$$

it follows that the concentration of the sulfur as ion will vary inversely as the square of the concentration of the hydrogen, and therefore, if the solution be diluted one-half, the concentration of the sulfur as ion will be nearly four times as great as before. Since the dissociation of the antimony chlorid or tin chlorid increases very rapidly with the dilution owing to the decrease in the concentration of the chlorine as ion it follows that a point must be reached when one or both of them will be precipitated. This point will of course be that at which the product of the concentration of the antimony or tin as ion and if the sulfur as ion has reached the precipitation value.

That substances having the smallest precipitation value will appear first then that having the next larger. The values for the sulfids of tin and antimony stand in this order,

$$Sn\ S > Sn\ S_2 > Sb_2\ S_3.$$

Therefore the antimony sulfid appears first, then the stannic, and last the stannous sulphid.

One-tenth of a milligram of arsenic is easily detected even in the presence of a gram of antimony. The limit for antimony and tin is naturally somewhat higher

If other metals precipitated by hydrogen sulfid are present they are all precipitated together and the arsenic, antimony and tin dissolved by yellow ammonia sulfid and represented by dilute hydrochloric acid and filtered off and redissolved in concentrated

hydrochloric acid with the addition of $KClO_3$, if necessary, the chlorine driven off by gentle heat and the solution treated as before.

Since a concentrated solution of hydrochloric acid becomes weaker on heating it will be necessary to add more acid before passing in the hydrogen sulfid.

Of course after this treatment everything will be in the highest oxidized condition and hence the original solution must be tested for their condition there.

The dark color of the stannous sulfid is much more intense than the yellow of the stannic, so it is well in many cases to reduce the tin by dissolving a small fragment of zinc in the solution before passing in the hydrogen sulfid.

Annotated Catalogue of the Crayfishes of Kansas.

BY J. ARTHUR HARRIS.

In 1886 Dr. Walter Faxon published a "Preliminary catalogue of the crayfishes of Kansas."[1] Since our knowledge of the Kansas forms is somewhat more extensive at present, and there is some later literature, as well as for the convenience of those who desire to study the distribution of this group of crustaceans in our state, it has been deemed advisable to bring this catalogue up to date.

To a certain extent I have followed the form of Dr. Faxon's catalogue, but have made some changes which I believe will increase its convenience and value.

In referring to the literature, wherever a species is described in a paper, the name under which it is described is given. When no specific name is given in the reference to the paper, it is to be understood that the paper deals with other than the description of the species. In most cases the nature of the paper is indicated. In giving the localities the name of the collector is given and after this, in parenthesis, the paper in which the species was reported. When this is not given it is understood, of course, that it is here reported for the first time. When no collector is named the material was collected by the writer. In quoting the literature, if the Bibliography number is followed by no designation as to what form is described, it is understood that the description covers the first- and second-form male and the female. In case the description does not cover these forms those described are given.

While mistakes will probably be found in citations of literature, the writer has made an earnest effort to give credit just where it belongs, and to place at the disposal of anyone who may wish to work on Kansas crustaceans as complete an index to the literature of this genus as possible.

1 Bull. Washb. Coll. Lab. Nat. Hist., vol. 1, p. 140, 1885.

1. **Cambarus simulans** Faxon.

C. simulans, Faxon, '84.

C. simulans, Faxon, '85, with fig. of male, F. I, and abd. app. of male, F. I and II.

1. Tributary of Medicine river, Barber county (coll. Washb. Coll.), Messrs. Williams and Craigin, coll. (Faxon, '85, b.).

2. Fort Hays, Ellis county (coll. Mus. Comp. Zool.) (Faxon, '85, b.).

2. **Cambarus gallinas** Cockerell and Porter.

C. gallinas, Cockerell and Porter, 1900.

The material noted below I assign only provisionally to this species. The specimens were collected during the summer of 1900, and placed in my hands. A full description was prepared and was in the publisher's hands when my attention was called to the paper by Cockerell and Porter. My material seems to agree quite well with that of Cockerell, but I wish to compare specimens of *C. simulans* Faxon as well as the material from New Mexico, which Professor Cockerell has been so kind as to present to the collection of the University of Kansas, before I assign this material finally to a species.

1. A slough, near Halstead, Harvey county, Kansas, (coll. U. of K.) W. J. Baumgartner, coll.

2. A small branch of the Chikaskia river, six miles northwest of Caldwell, Sumner county, (coll. U. of K.) T. J. Kinnear, coll.

In July, 1900, Mr. Baumgartner took a part of the material in a slough, which connected in wet weather with a creek not a mile away. The water was running more than usual on account of a recent rain. No burrows were observed at this time. About November 10 he again visited the locality and secured more material. This time the animals were found in burrows. One of these, about one foot deep, had its mouth below the surface of the water. The others were along the bank close to the water's edge. "Chimneys" were not very conspicuous. The burrows themselves, so far as noticed, were unbranched, about three inches in diameter and extending almost straight down for a distance not over one and one-half feet. One animal was found in each burrow.

Mr. Kinnear's material—two small specimens, each slightly over an inch in length—was taken in a little running stream.

3. **Cambarus gracilis** Bundy.

C. gracilis, Bundy, '76, male F. I and female.

C. gracilis, Bundy, '70, male F. I and female.

C. gracilis, Bundy, '82, male F. I and female.

C. gracilis, Faxon, '85, male F. I and female, with figs. of first abd. app. of male F. I.

C. gracilis, Hay '96, male F. I and female, with sketch of carapace, lamina, annulus ventralis and abd. app. of male F. I.

1. Labette county, W. S. Newlon, coll. (Faxon '85 b).

2. Douglas county. Stagnant ponds in early spring and burrows later in the summer.

Being a burrower, *C. gracilis* is one of the species which is hard to obtain, especially the males, and this probably accounts for the meager reports of its distribution. Mr. H. Garman says[1] that he has examined hundreds of specimens taken along water courses in the neighborhood of Normal, Illinois, and has not found a dozen males. Hay '95 says: "It is a burrower, coming forth probably only during the breeding season in the early spring when it inhabits the water courses." I have found this species very plentiful near Lawrence in stagnant ponds in early spring, but I have never known of its being taken in running creeks. In one pond which I watched carefully, the females appeared March 13, 1900. The males did not appear until April 15, when in company with some some other collectors I secured one. Some days later Professor McClung and Mr. Baumgartner took another at the top of its burrow in a pasture not far from the pond mentioned above.

I have not succeeded in determining the date of copulation or laying of eggs. The eggs in the ovaries of females taken in the spring were by no means fully developed. I have found some females carrying young in the early spring.

In August Mr. Martin and myself took two males and one female from the mouth of their burrows. These burrows were in a yard some distance from a running stream but where the ground was inclined to be somewhat wet in rainy weather. They came up at night and sat at the mouth of their burrows, probably watching for prey, and dropping back in at any sign of danger. The animal does not seem to be entirely nocturnal in its habits and is not unfrequently found at the top of its burrow in the daytime.

The low lands in which these crayfishes live are not unfrequently flooded at times of great rainfall. In this case the animals emerge from their burrows and upon the subsidence of the of the water may be fonnd wandering around over the surface of the ground.

The females which I have examined of this species are olive

1 Faxon '85, p. 58.

green, the males almost a salmon red. I have been told by people from various parts of the state of the numbers of red crayfish which they have seen after a heavy washing rain, and since, so far as I know, this is the only very red species we have in this region, I believe that careful collecting will show this to be one of our most widely distributed species.

Individuals of this species must exuviate in their burrows. I have watched very carefully the ponds in which the females are found in early spring but have never found a specimen which was at all soft from exuviation. As noted above, in the spring females are occasionally found in these ponds with a *few* young which are old enough, or nearly old enough, to leave the parent. This makes it seem altogether probable that those females without young have lost them before or immediately upon taking to the open water. In *C. immunis* Hagen, the females exuviate in the spring as soon as the young abandon them, but this would seem to indicate that such is not the case with *C. gracilis*.

In the fall of 1900 there were many young crayfishes, which seemed to be *C. gracilis*, in the ponds from about October 20 to November 20. They appeared in great numbers at about the same time as *C. immunis* disappeared. I also noticed young of this species early in the spring of 1900. So it appears that young and adult *C. gracilis* appear in the ponds early in the spring, and that the young again appear late in the fall, after other species have gone to their burrows.

These young crayfish which were from three-fourths to seven-eights of an inch in length when they disappeared in November, 1900, appeared again about the first of March, 1901. They were then taken in great numbers. A few days later the ponds froze over but the animals were still to be found, apparently as plentifully as ever, under a layer of ice about one inch thick. This spring the old animals did not appear until after the young. The young grew rapidly and by the first of May had attained a length of from one to nearly one and a half inches. Many smaller animals about five-eights of an inch in length are now—May 9,—found in the ponds and ditches. These are probably the young of *C. gracilis* which were still carried by the female as late as March 27.

I might add that as compared with some other species, *C. immunis*, for instance, the per centage of mutilation in this species is very small. It is very seldom that one finds an individual with one of the great claws wanting or showing any indication of having been regenerated.

4. Cambarus diogenes Girard.

C. diogenes, Girard, '54, with notes on burrowing habits.

C. obesus, Hagen, '70, with fig. of male, F. I, abd. app. of male, F. I and II, lamina, epistonia, and "spina externa."

C. diogenes var. *ludovicianus*, Faxon, '84.

C. diogenes, Hay, '96, with sketches of carapace, lamina, annulus ventralis and abd. app. of male, F. I. and II.

Notes on variation, habits, etc., Faxon, '85.

Burrows of *C. diogenes*, Tarr, '84.

Burrows of *C. diogenes*, Abbott, '84.

1. Leavenworth, Leavenworth county (coll. Mus. Comp. Zool.), (Faxon, '85 b).

2. Lawrence, Douglas county (coll. U. of K.), L. A. Adams, coll.

C. diogenes has been reported from only the two adjoining counties, Douglas and Leavenworth. Probably the reasons for the meager ness of the reports of the occurrence of this species and *C. gracilis* are the same, both being burrowing species. I am inclined to think, however, that *C. diogenes* is not abundant in Douglas county.

Hay, '96 reports this species as laying their eggs from April 18 to 30. According to him the early spring when they come forth to breed and lay their eggs is the only time they are a noticeable member of the fresh water fauna. Hay's observations were, of course, made in Indiana but would probably hold good for Kansas as well.

May 3, 1901, M. W. Blackman and M. Truehart secured a female of *C. diogenes*. The swimmerets were loaded with eggs in a not very late stage of development. I examined the same ditch four days later. There were many burrows in the bank but no adult individuals were taken. This would seem to indicate that the eggs passed through the most of the stages of their development while the animals are in the burrows, as is certainly the case with *C. gracilis*. The females of *C. immunis* must also pass the winter with their eggs in the burrow, but come out early in the spring to complete the process of hatching. *C. gracilis* probably lays its eggs while in the burrow and when the ponds dry up early in the fall. *C. immunis* perhaps does also.

C. diogenes is one of our large species, the specimen from Douglas county being nearly 110 mm. in length.

C. diogenes will probably prove to be one of the widely distributed species. I have material from near Boulder, Colorado, kindly sent me by Professor Ramaley of the University of Colorado. *C. dioge-*

nes is the only crayfish yet reported from Colorado. In a letter of October 12, 1900, he says: "We find crayfish here in ditches and ponds much as in other localities, but as most of the ditches are dry part of the year the animals are not abundant. Our streams are mostly swift running and crayfish are seldom found in them. I have not noticed the animal at high altitudes but they may occur there, doubtless up to 8000 feet at any rate."

5. Cambarus immunis Hagen.

C. immunis, Hagen, '70, male, F. I, and female. with figs. of chela, epistoma, lamina, "spina externa," and abd. app. of male, F. I.

C. signifer, Herrick, '81, with fig. of rostrum, lamina, and abd. app. of male, F. I and II.

C. immunis, Forbes, '76, male, F. I and young.

Notes on variation and literature, Faxon, '85.

C. immunis, Hay, '96, with sketch of carapace, lamina, annulus ventralis, and abd. app. of male, F. I and II. Also Notes on Habits.

Habits, Harris, '01.

1. Leavenworth, (coll. Acad. Nat. Sci., Phila.) (Faxon, '85).
2. Ellis, coll. G. H. Gilbert (Faxon, '85).
3. Douglas county, in stagnant ponds (coll. U. of K.).

C. immunis is to be looked for in shallow, stagnant ponds and roadside ditches where it is often found in immense numbers. Upon the drying up of the ponds the animals retire to burrows along the edge. For a more complete discussion of the habits of this species see Harris, '01.

5a. Cambarus immunis Hagen, var. **spinirostris** Faxon.

C. immunis, var. *spinirostris* Faxon, '85, male, F, II and female, with fig. of cephalothorax of male, F. I.

C. immunis var. *spinirostris*, Faxon, '85 b, male F. I.

C. immunis var. *spinirostris*, Hay, '98, with sketch of carapace.

1. Ward's Creek, Shawnee county (coll. Washb. Coll.), F. W. Cragin and J. B. Fields, coll. (Faxon, '85 b).
2. Stagnant ponds, Douglas county (coll. U. of K.).

6. Cambarus nais Faxon.

C. nais, Faxon, '85, b.

C. nais, Faxon, '90.

1. Labette county (coll. Washb. Coll.), W. S. Newlon, coll. (Faxon, '85 b).

2. A small branch of Coal creek, Montgomery county (coll. U. of K.), L. M. Peace, coll.

The branch of Coal creek in which Mr. Peace collected this material is fed by many springs all along its course. It winds between rocky hills and has in many places a smooth stone bottom. It is very stony, the stone being sandstone. The depth varies, being in some places eight or ten feet deep and at a short distance away only a few inches. It sometimes goes dry in places, owing, probably, to the failure of some of the many springs which feed it.

7. **Cambarus virilis** Hagen

C. virilis, Hagen, '70, with fig. of male, F. I, hand of var. A, male, abd. app. of male, F. I and II and variety, lamina, epistoma, "spina externa."

C. debilis, Bundy, '76, male, F. II.

C. debilis, Bundy, '82, male, F. II.

C. debilis, Bundy, '83, male, F. II.

C. couesi, Streets, '77, (Forms?).

Note, Bundy, '77.

C. virilis, Bundy, '83, (Forms?).

C. virilis, Hay, '96, with sketches of carapace, lamina, annulus ventralis and appendages of male, F. I and II.

Note on the color of the living *C. virilis*, Streets, '77.

Notes on occurrence of first- and second-form males, Herrick, '81.

Notes on variation, etc., Faxon, '85.

1. Tributary of Kansas river, Shawnee county (coll. Washb. Coll.), F. W. Craigin, coll. (Faxon, '85, b.).

2. Wards creek, Shawnee county (coll. Washb. Coll.), J. B. Fields and F. W. Craigin, coll. (Faxon, '75, b.).

3. Wabaunsee county (coll. Washb. Coll.), J. B. Fields, coll. (Faxon, '85, b.).

4. Garden City, Finney county (coll. Washb. Coll.), F. W. Craigin, coll. (Faxon, '85, b.).

5. Leavenworth, Leavenworth county (coll. Acad. Nat. Sci. Phila.), (Faxon, '85, b.).

6. Manhattan, Riley county (coll. Acad. Nat. Sci. Phila.), (Faxon, '85, b.).

7. Republican river, northwest of Fort Riley (coll. Acad. Nat. Sci. Phila.), (Faxon, '85, b.).

8. Ellis, (coll. Peabody Acad. Sci. Salem,) Dr. L. Watson, coll. (Faxon, '85, b.).

9. Sappa creek, Oberlin, Decatur county (Faxon, '90).

10. Osage river, LaCygne, Lynn county (Faxon, '90).

11. Topeka, Shawnee county (Faxon, '90).

12. Spring at head of Medicine Lodge river, Kiowa county (coll. Washb. Coll.).

13. Stagnant ponds, Douglas county (coll. U. of K.).

14. Rock creek, Douglas county (coll. U. of K.), C. D. Bunker, coll.

15. Washington creek, Douglas county (coll. U. of K.).

16. Coon creek, Douglas county.

17. Wild Horse creek, Jefferson county (coll. U. of K.).

18. Dickinson county (coll. U. of K.), Walter Meek, coll.

19. A small branch of Chikaskia river, six miles northwest of Caldwell, Sumner county (coll. U. of K.), T. J. Kinnear, coll.

20. Small stream near Egerton, Wyandotte county (coll. U. of K.), Miss Metta Haines, coll.

21. Labette creek, within city limits of Parsons, Labette county (coll. U. of K.), R. B. Brewster, coll.

22. It might not be out of place to add that I have seen material collected in Kansas City, Missouri.

C. virilis is found principally in running streams, although it is frequently taken in the same locations as *C. immunis*. While I have never taken *C. virilis* from burrows, I have no doubt that the great numbers of burrows which we see running back into the banks of the creeks just a little below the water-line belong to *C. virilis*. When living in the same sort of location as *C. immunis* it doubtless burrows in the same manner. A specimen from Kansas City, Mo., handed me for study by Mr. R. E. Scammon, was found by laborers nine feet under ground and over one hundred feet from water.

C. virilis seems to prefer rocky rather than muddy places. May 5, 1900, I collected this species in Wild Horse creek, Jefferson county. At the rocky 'riffles' the crayfish were taken in abundance, but, perhaps, 150 yards above, where the bottom was composed of soft, deep mud I did not secure a single specimen. I have noticed the same thing in Coon creek, Douglas county, and my friend, Mr. C. D. Bunker, tells me that in Rock creek, Douglas county, he has noticed that the animals are to be found only in the rocky places.

I cannot say whether it is a dislike on the part of the animal for the mud which causes it to select the rocky parts of the stream, or whether it finds among the rocks more ready protection from its enemies. So far as I have been able to observe, food would be just as plentiful, if not more so, in the slower-running, muddy

parts of the stream than at the rocky 'riffles.' *C. virilis* can, and does, live in muddy places. As mentioned above, it is sometimes found in muddy ponds and roadside ditches with *C. immunis*, and I have taken a great many from Washington creek, Douglas county, where the mud is as soft and deep as in either of the creeks mentioned above.

In the winter *C. virilis* may be found under flat stones in the rocky creeks, even when the water is covered with ice. When taken from the water they are so numb as to be almost incapable of movement, but liven up when held in the hand for a short time and are as active as ever after a few hours in the laboratory.

The eggs are laid in the spring, none being found on the females collected during the winter. The ovarian eggs of specimens taken in January seem to be fully developed, so far as may be seen from examination with the naked eye.

C. virilis seems to be the most widely distributed species in our state, being reported from fifteen different counties.

8. Cambarus rusticus Girard.

C. rusticus, Girard, '52.

C. rusticus, Hagen, '70. Descriptive notes, with figs. of abd. app. of male, F. I and II, lamina, epistoma and "spina externa."

C. placidus, Hagen, '70, with figs. of abd. app. of male, F. I and II, lamina, epistoma and "spina externa."

C. juvenalis, Hagen, '70, with figs. of abd. app. of male, F. I and II, lamina, epistoma, and "spina externa."

C. wisconsiensis, Forbes and Bundy, '76, male.

C. wisconsiensis, Bundy, '82, Form ?).

C. wisconsiensis, Bundy, '83 (Form ?).

C. rusticus, Faxon, '84, note.

C. rusticus, Faxon, 85, with figs. of abd. app. of male, F. I and II.

C. rusticus, Hay, '96. with sktches of carapace, lamina, annulus and first abd. app. of male, F. I and II.

1. Osage river, La Cygne, Linn county (Mus. Comp. Zool.), (Faxon, '90).

9. Cambarus pilosus Hay.

C. pilosus, Hay, '99, male, F. II, with sketch of carapace, lamina, and abd. app.

1. Beloit, Mitchell county (coll. U. S. Nat. Mus.), (Hay, '99).

2. I refer to this species with a little hesitation, material collected in Russell county (coll. U. of K.), W. S. Sutton, coll.

Mr. W. S. Sutton, of the Department of Zoölogy, University of Kansas, who collected the above material, kindly furnished me with some observations on their habits. He found them July 14, burrowing under tussocks of grass on the edge of a small stream in Russell county, Kansas. A first-form male and a female were usually found in each burrow, both taking part in the work of excavation. The whole burrow was under water, running back at first horizontally, then sometimes downward at various angles. The burrows examined ranged from fifteen to twenty-five inches in length and were somewhat enlarged and sometimes branched at the end.

In burrowing, the mass of mud was pushed out in front of the animal, being held between the anterior end of the animal and the chelae, which were held with the inner magins close together, while the meros was held well up and close to the body, thus forming a sort of prismatic or pyramidal shaped space between the chelae and the anterior end of the thorax. Mr. Sutton is firmly convinced that the mass of mud was held between the chelae and the body to prevent the mass from going to pieces while being moved along in the water, since when a stone was to be removed it was simply pushed along in front of the chelae.

As was stated above the whole burrow was made under water, and no attempt was made to construct anything like a 'chimney' out of the mud removed. This was simply pushed out of the mouth of the burrow thus forming a 'dump' such as is frequently seen at the mouth of hillside coal mines. The crayfishes which build regular chimneys usually burrow at night, but these specimens were actively at work at noon, when they were taken.

10. Cambarus neglectus Faxon.

C. neglectus, Faxon, '85 b.

C. neglectus, Faxon, '90.

1. Mill creek, Wabaunsee county (coll. Washb. Coll.), F. W. Craigin and J. B. Fields, coll. (Faxon, '85, b).

2 Republican river, near Guy, Cheyenne county (coll. Mus. Comp. Zool.), (Faxon, '90).

3. Sappa creek, Oberlin, Decatur county (coll. Mus. Comp. Zool.), (Faxon, '90).

This is so far the only species with a carinated rostrum reported from our state and for this reason it will be all the more easily recognized. It has been collected from various localities in Arkansas, Missouri and Texas by S. E. Meek (see Faxon, '98), and a determination of its distribution in our state is desirable.

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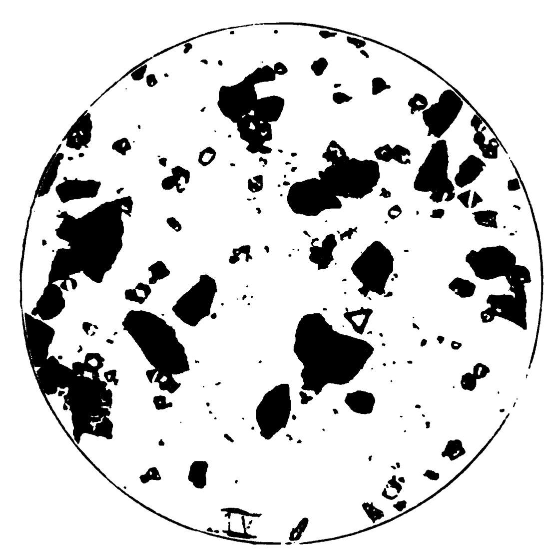


Fig. 1. Suspected Sample X 75.

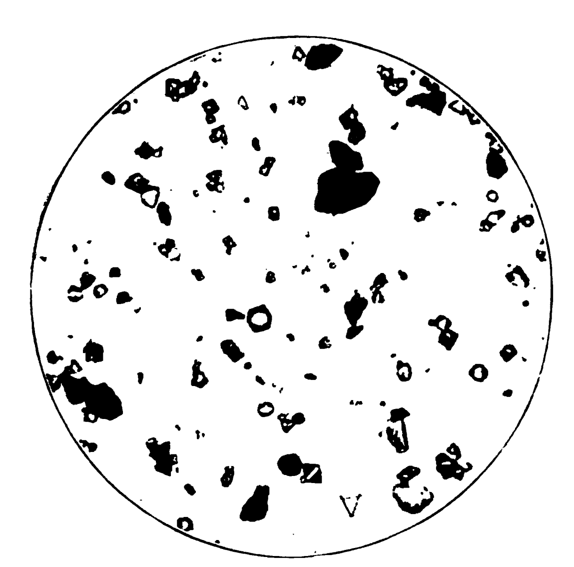


Fig. 2. Suspected Sample X 75.



Fig. 3. Arsenic from whisky X 75.

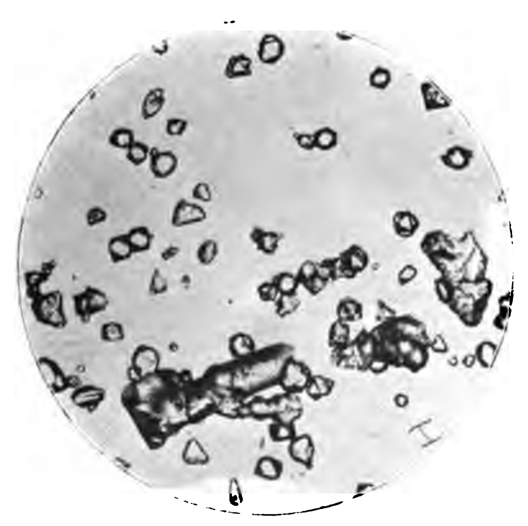
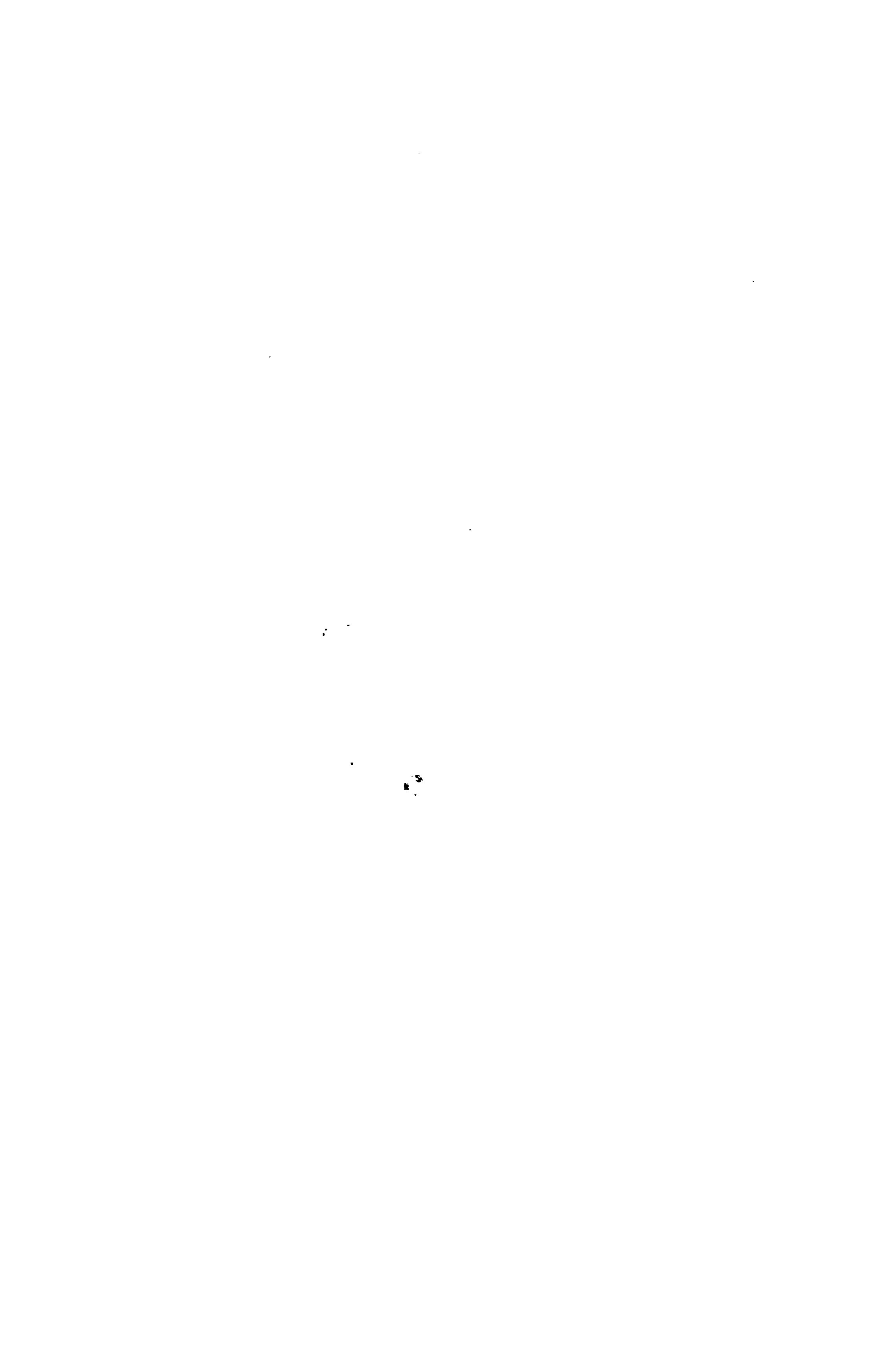


Fig. 4. Arsenic from malted milk X 75.



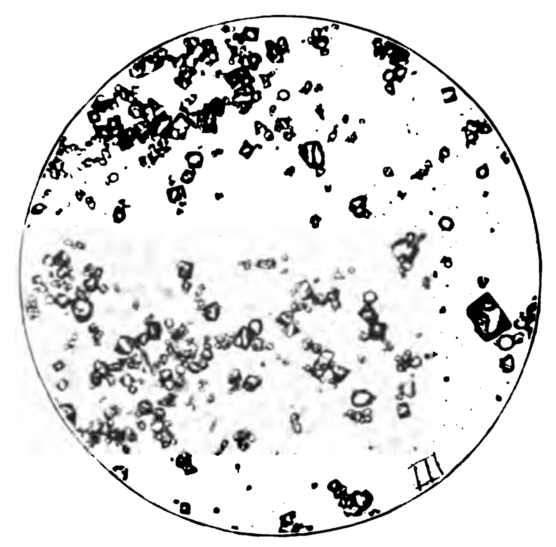


Fig. 5. Arsenic from chemical laboratory X 75. Mostly crystalline particles.

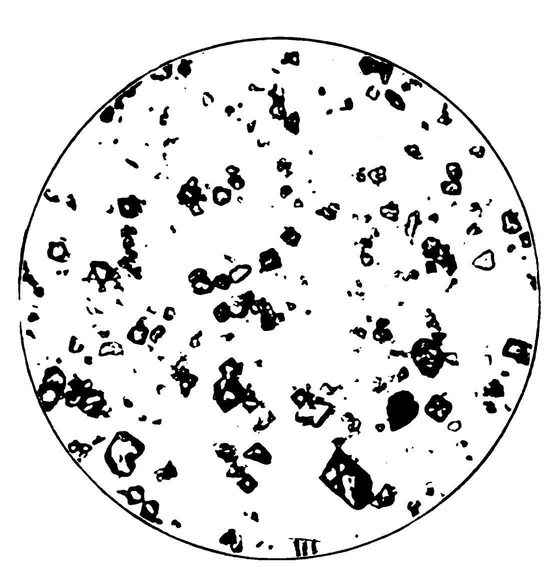


Fig. 6. Arsenic from pharmacy laboratory X 75. Mostly amorphous particles.

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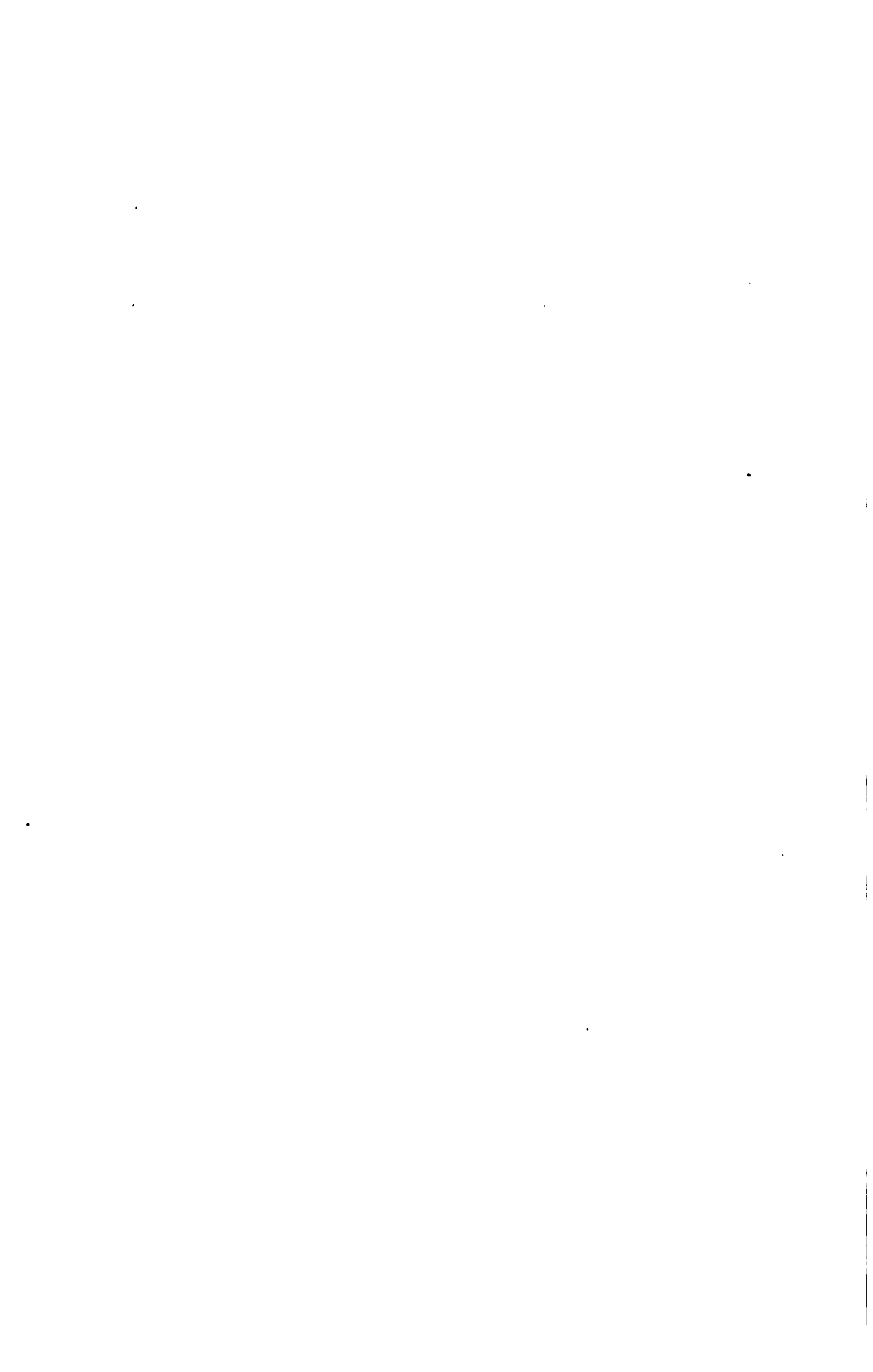
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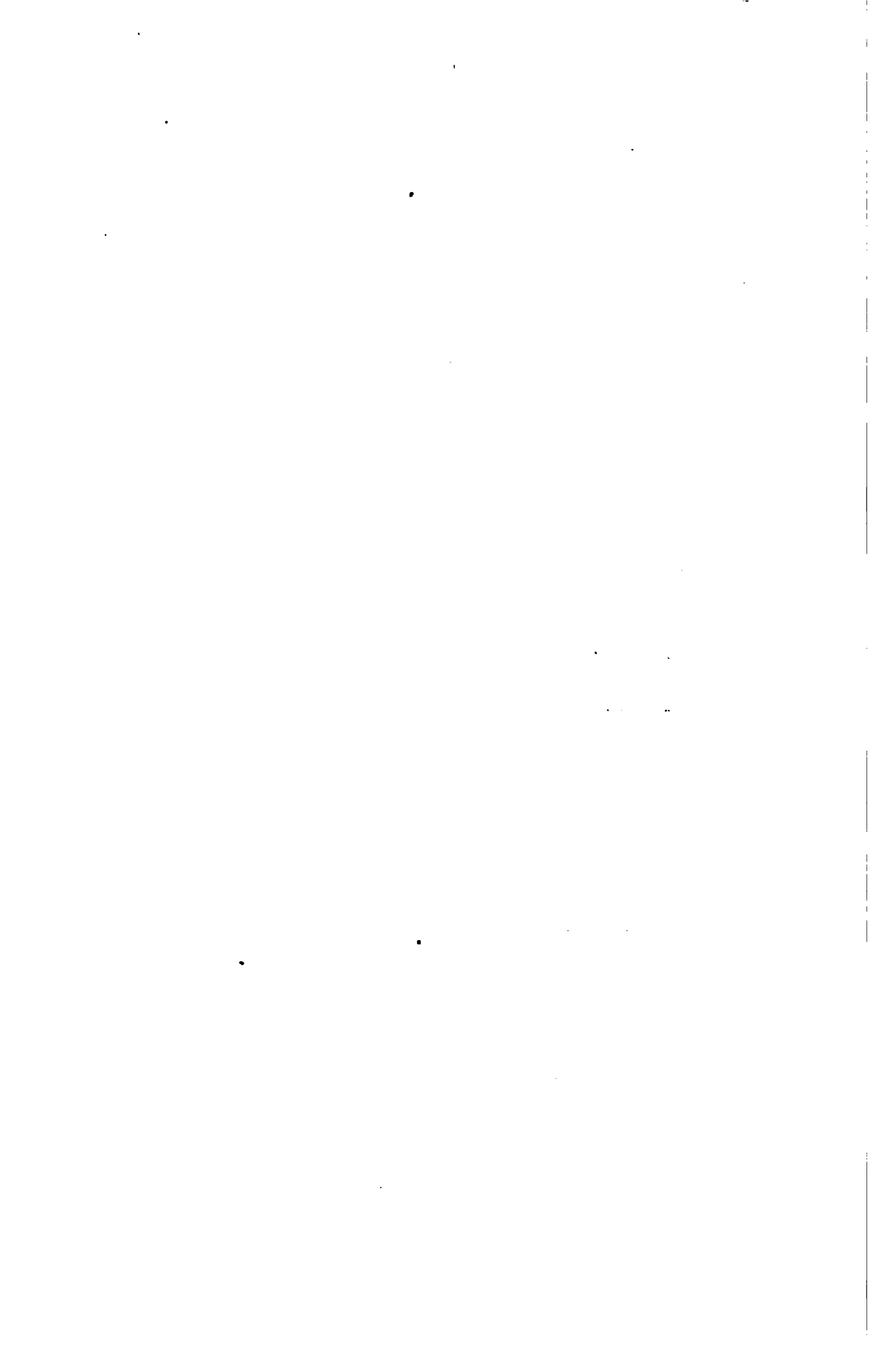
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VOL. X. JANUARY, 1901. NO. 1.

Permian Plants—Taeniopteris of the Permian of Kansas.[1]

Contribution from the Paleontological Laboratory No. 58.

BY E. H. SELLARDS.

With Plates—I, II, III and IV.

The fern genus, *Taeniopteris* Brongniart, is well represented in number of individuals, in the Kansas Permian Flora, on which the author is working, and presents aside from the presence of at least two species and one variety, some interesting features. The rachises of several of the ferns bear elliptical scars, which, as I will attempt to show, are very similar to, if not identical with the scars on *Macrotaeniopteris magnifolia* (Rogers) Schimper from the Richmond coal fields of Virginia, Jurassic, regarded by some authors as scars marking the position of the sori of the genus. The second character of especial interest is the presence between the veins of small, oval resistent bodies, sporangia (?), fungi, or possibly interneural glands. The plants described come from three miles south and one-half miles east of Banner City, Dickinson county, Kansas; a few also from the same horizon three miles south of Carlton, Kansas. They were collected in part by Mr. Charles Sterling of the University, and in part by the author. The formation is probably the Marion of Prosser. The plant horizon is within a few feet vertically of the plant-bearing Cretaceous strata. The photographs and drawings were made by the author, except figure 7, plate 1, made by Mr. Sidney Prentice.

1 Published by permission of the paleontologist of the University Geological Survey of Kansas.

The author is very much indebted to Dr. David White, curator of the Palaeozoic plant collections of the United States National Museum, not only for the kindest advice and suggestions, but for the favors of access to the collections in his charge, and assistance in finding the plants of most interest in their relation to the Kansas forms.

Systematic Description.

TAENIOPTERIS.

Brongniart. Prodrome, p. 61, 1828

Taeniopteris coriacea Goep. Plate I, Figs. 6, 8–12; Plate II; Plate III, Figs. 1, 2; Plate IV, Figs. 1, 3.

Taeniopteris coriacea Goeppert. Flora der Permischen Formation, p. 130, Plate VIII, Fig. 4; Plate IX, Fig, 2, 1865-1866.

Fronds simple (?), linear or very narrowly elliptical, coriaceous in texture, broadest in the middle, tapering to a symmetrical lanceolate apex, and a petiolate base, 8 to 20 cm. long, average width at the middle, 10 to 20 mm.; rachis strong at the base, rough with rather strong, longitudinal striae, about 3 mm. wide, reduced gradually in passing to the apex where it becomes a mere line; fronds slightly rolled at the borders; lateral veins numerous, strong, straight and parallel, cross the lamina obliquely, with a slight but distinct upward curve at the border, 28 to 32 per centimeter; veins near the base of the frond leave the rachis with a short curve, often forked once near their base; those at the middle of the frond only slightly curved at their union with the rachis, seldom forked; those near the apex not at all curved at their base, always simple, straight, or even arched upwards slightly in crossing the lamina; oval bodies, sporangia (?) on several of the fronds, situated between the veins, half immersed in the epidermis of the frond, ½ to ¾ mm. apart, six or seven between each two veins; elliptical elevations, or corresponding depressions occur on or near the rachis of several specimens.

The species is a common one, and is represented by many good specimens. By reason of the thick resistant texture, the frond is usually well preserved, and forms a natural line of cleavage in the matrix, which often breaks so as to expose its entire length. The individual specimens vary a good deal in size, but can usually be readily recognized by their straight, oblique, strong nerves, resistant texture, and lanceolate apex.

The agreement with Goeppert's types is not entirely complete, but essentially so. Goeppert's figures do not show a rolled border,

nor does he mention such a character in his description; but this character is not always evident, and possibly not always present.

I have considered the frond as probably simple, as there are no indications of a pinnate character, and it has the same shape as other *Taenioptorids* with supposedly simple fronds. The peculiarities of venation noted in the above diagnosis—veins near the base of the frond more curved at their union with the rachis, often forked, while those at the apex are only slightly curved, seldom forked,—are seen also in the figures of the European specimens. The texture and shape of the fronds also agree. The fact that the oval bodies between the veins have not been previously observed may be due to the rarity of the species and the few specimens heretofore obtained. The scars on or near the rachis, whether the result of fungi or of insect stings may have been absent on the European specimens.

The slightly thickened and rolled border of this species might be taken to indicate the presence of a border vein—a supposition to which the upward curve of the veins at the border adds strength. But if such a character belongs to the species, it is not sufficiently preserved on any of the specimens at hand to be recognizable. Such a character, if it exists, would bring the species into comparison with the Mesozoic genus *Oleandridium*, some species of which it otherwise closely resembles.

The species seems to have been found as yet in only two other localities, both Permian, Ottendorf in Bohemia, and Lissitz in Moravia, both recorded by Goeppert, l. c. The specimens known of the species heretofore have all been somewhat fragmentary.

Taeniopteris coriacea var. **linearis** n. var. Plate III. Figs. 3, 4.

Fronds smaller, more narrowly linear, apex very acute, average width 7 to 20 mm , average length about 14 cm., thinner in texture, venation apparently thinner, and perhaps closer.

The difference between the extreme forms of this variety and the specimens typical of the species is very great, and if there were no intermediate forms would undoubtedly be considered of specific value. But between the extremely narrow fronds such as figured plate III, fig. 4, and those typical of the species, plate II, figs. 1 and 2, there are such continuous gradations that I am entirely unable to draw any separating line. The venation of the smaller fronds seem thinner, but becomes proportionally stronger with the size of the frond. The apex, however, is decidedly more acute. The species and variety occur at the same locality.

Taeniopteris newberriana F. and I. C. W. Plate I, Figs. 1-5, 13, 7 (?), Plate IV, Figs. 2, 4

Taeniopteris newberriana Fontaine and I. C. White, Permian, or Upper Carboniferous Flora of West Virginia and Southwest Pennsylvania, p. 91, plate 34, figures 1-8, 1880.

Numerous specimens in the collection are so close to *Taeniopteris newberriana* that their reference to that species, at least for the present, seems advisable. There are numerous individuals, but all more or less fragmentary. Owing to the thin texture of the frond the line of cleverage in the matrix is not sufficiently marked to expose it completely as in the last species. In this character of a very thin frond our specimens differ very markedly from the types of the species, which are described by the authors as rather thick and coriaceous. The fact that the matrix is different in the two cases, ours being preserved in limestone, while theirs were in shale, may account in part for this, and possibly for other seeming differences. The nerves are figured by the authors as leaving the rachis at right angles, but in the description they say that the lateral nerves leave "the midrib at a right angle, or with a very slight arch immediately at the insertion." In our specimens the veins near the apex of the frond leave the midrib at right angle, those near the middle with a slight arch immediately at the insertion, and those near the base with a more decided arch at the insertion. In the figures of the types the veins are represented as coming out at right angles from the rachis throughout the entire length of the frond, the base as well as the apex. No specimens have been found in the Kansas formation with the peculiar segmentation characterizing many of the Virginia specimens. These two characters—difference in the origin of the veins, and absence of the segmented frond, may prove to be specific differences separating our species from Fontaine and White's. The present reference is intended as suggestive rather than final. In other respects Fontaine and White's description of the venation, "lateral nerves very fine, closely placed and immersed in the parenchyma of the frond," entirely agrees with our species, as does also their description of the size and shape of the frond, "frond, simple, elongate, narrowly eliptical, tapering slowly to the apex and base." The largest frond of our specimens are 17 to 23 mm. wide, probably not less than 20 cm. long; the Virginia specimens are 2¾ cm. wide, and have an estimated length of 20 cm.

Fontaine and White compare the species to *T. coriacea*. It differs from specimens of that species from the same locality, in a larger and much thinner frond, finer and more numerous veins,

more nearly at right angles to the rachis. The two species are usually easily separated on these characters, but between the larger fronds of *T. coriacea* and the smaller of *T. newberriana* as represented in the Kansas Permian, the dividing line is sometimes by no means clear.

The species may be compared in venation to *T. jejunata* Grand' Eury, but this latter species is described as having a pinnate frond, of which the ultimate pinnae have a somewhat cordate base. *T. newberriana* has a simple frond gradually reduced to a petiolate base, as shown both by the Virginia and Kansas specimens. Professor Potonié, Die Flora des Rothliegenden von Thuringen, p. 145, includes in the synonomy of *T. jejunata*, "*T. newberriana* Font. and White ex parte" and cites plate XXXIV, figures 9, 9a, of the Permian Flora, but the figures referred to are not of *T. newberriana*, but of *T. lescuriana* F. and I. C. W.

The horizon from which the types of *T. newberriana* were described have been variously regarded as Permian and Permo-Carboniferous. Professors Fontaine and White in their treatment of the flora argue strongly for its Permian age.

Taeniopteris sp. Plate I, Fig. 14.

I figure here the apical part of a frond which is, probably, different from either of the other species. The venation has much the same character as that of *T. coriacea*, but the frond is evidently much larger. On the other hand the veins are very much more oblique than those of *T. newberriana*. The veins are thin and close, and the dots between the veins small and numerous.

Interneural Bodies on the Fronds of Taeniopteris.

The interneural bodies referred to in the introduction occur on some specimens of each species and variety of *Taeniopteris* in the collection. They are small, oval, resistant bodies, situated between the veins, half immersed in the epidermis of the frond, nearly globular in shape, some smooth on top, but more often showing a slit across the top or side very suggestive of the slit for the discharge of spores in many eusporangiate ferns. The slit, apparently, has no regular position on the bodies; it is sometimes across the top, sometimes on the side, sometimes parallel to the direction of the veins, or again transverse to the veins. The bodies, when removed from the epidermis leave a cup-shaped cavity. In many of the cavities there is a cast of the slit, indicating that many of the bodies had the break turned down, and doubtless many of those appearing smooth on top are slit below.

Some of the sporangia(?), however, are certainly not slit in the manner described. One specimen of *T. newberriana* having many of the bodies preserved, has none showing the slit, and when removed and mounted they are seen to be round and entire. If we accept the hypothesis that the bodies in question are sporangia, the absence of the cleft in this specimen would naturally find its explanation in the supposition that the sporangia are not yet mature.

The size and number of the sporangia seem to be characters of specific value. On the group of specimens which I have referred to, *T. coriacea,* they are proportionally large, readily visible to the eye, more distant and fewer than in the other species. The bodies between the veins of *T. newberriana* (?) are smaller—although the frond is larger—closer together, and scarcely visible without the aid of a lens.

When the matrix holding the specimen is opened some of the bodies always adhere to one side and some to the other, so that either side of the specimen shows some in place and casts of others. Under a lens the bodies show distinctly. Examined under a high power with reflected light the details seen with the lens come out more definitely, the bodies appearing bright yellow in contrast with the dark substance of the frond Figures 4 and 5, plate I, are sporangia(?) taken from a specimen of *T. newberriana* (?) showing slits, one across the top, the other across the side. Figures 10 and 11 show two bodies taken from *T. coriacea,* and figure 12 a cast. All enlarged thirty diameters.

The bodies may be readily removed from the frond and imbedded and sectioned by grinding. On touching the epidermis with moulding wax many of them adhere and may be transferred to the desired media for sectioning. The author used for this purpose, hardened balsam and sealing wax. Of the numerous sections made none showed conclusive evidence of cellular structure—the one remaining point necessary to prove that the bodies are sporangia. Irregular markings resembling cell walls are often seen, but nothing definite. Thin sections under a high power appear minutely granular with redish-yellow granules. Chemical test shows the presence of iron, and other appearances suggest iron oxide as their probable composition.

Analogous appearances in other genera of plants—Nilssonia.

Some species of *Nilssonia* Brong., a Mesozoic genus referred to the cycads by some authors, to the ferns by others, have dots between the veins very suggestive of those of *Taeniopteris*. The dots

on *Nilssonia polymorpha* Schenk are described as small, situated at approximately regular distances apart, between the veins. The dots of this species have been variously regarded by different authors. Schenk regarded them as the remains of sori and accordingly referred the genus to the ferns.[1] Saporta considered them more like fungi and referred the genus again to the cycads.[2] Count Solms Laubach, Fossil Botany, p. 140 (Balfours translation), in summing up the evidence considers Schenk's view more probable than Saporta's, and therefore treats of the genus among the ferns. Later authors have generally referred the genus to the cycads. Another interesting point of analogy between those specimens of *Nilssonia polymorpha* having unsegmented pinnae and the *Taeniopterids* under consideration is the striking similarity in the shape and venation of the apical part of the frond. In both the midvein is reduced to a mere line, but continues to the apex, the lateral veins are arched upwards, with numerous dots between them.

Neuropteris.

A specimen of *Neuropteris* in the Lacoe collection of the United States National Museum, which Dr. White had the kindness to show me, has dots between the veins very suggestive of the oval bodies between the veins of our specimens of *Taeniopteris*. Dr. White is inclined to regard these dots as glands. The species is described in an unpublished manuscript of Lesquereux, which Dr. White is now editing.

Alethopteris.

Andrews described in Vol. II, pal. Geol. Surv. of Ohio, p. 421, pl. 50, figs. 3-3b, a species from near the base of the coal measures of Ohio, under the name *Alethopteris maxima* And., which has numerous small dots between the veins. Andrews regarded these as probably dots of iron oxide. Lesquereux, Coal Flora, p. 187, refers to them as "remants or the base of scales similar to those often seen upon leaflets of species of *Acrostichum*."

Megalopteris

Dots occur between the veins of *M. Harttii* And. and *M. dentata* in the museum collection, from Rushville, Ohio, very like those on *Taeniopteris*.

1 Die fossile Flora der Grenzschichten des Keupers und Lias Frankens, 1868.
2 Paleontologie francaise, ser. 2, vegetaux, vol. 2, 1875.

Other species of Taeniopteris.

Newberry figures the apex of a frond[1] with the following explanation of the figure: "*Taeniopteris* sp. (?) in fruit; summit of frond, Los Broncos, Sonora." The formation is considered Triassic. The specimen is not mentioned in the text. The figure is indistinct, but the dots seem to be small, close, and placed much as in our specimens, and are very probably the same.

Dots of the character of most of those mentioned above, whether glandular or fungal, or the bases of scales, if sought for will probably be found on many other species and various genera. Recently I have noticed very similar dots between the veins of an *Alethopteris* from Lansing, Kansas, probably *A. serlii* (Brong. Goep.

If the dots between the veins of all these various genera are the same as those on *Taeniopteris* the possibility of their being fructification is practically excluded. It is scarcely possible for genera differing so widely in form and geological position to have fructification so very similar. Two characters, however, are to be noted on *Taeniopteris* not present on any of the others: the dots are in the form of hard resistant bodies, which can be removed and sectioned, which seems not to be the case in any of the other genera; secondly, the slit in the bodies remains unexplained on any other theory than that these are sporangia and the slit the line of cleavage for the discharge of spores; to which might be added a seeming difference in the size and arrangement of the bodies on the different species. It might be argued against such an hypothesis that no genus of ferns is known in which the sporangia are placed between, and having no direct connection with the veins. In many genera they are placed between the forks, or at the ends of the veins, but always, so far as I have been able to learn, in direct connection with this source of nourishment. Such an arrangement, however, might not be impossible on a primitive fern. The solitary and distantly separated sporangia(?) are not peculiar to this genus. Several fossil genera are known in which the sporangia are often or regularly solitary; in the living genus *Angiopteris* the sporangia are independent of each other.

With the incomplete evidence at hand, especially in the absence of structual characters, no positive conclusion is possible, and the question is best left open for the present. The appearance is certainly very suggestive of sporangia, and in this journal, January,

1 Exploring expedition from Santa Fe to the Junction of the Grand and Green rivers, 1859, Macomb. Geological report by Newberry, pl. 8, fig. 5.

1900, the author referred to them as apparently representing a new type of fructification. Unfortunately the positive proof is still lacking.

Scars on or near the Rachis of Taeniopteris.

Several specimens of this genus bear on or near the rachis, elongate-elliptical scars, resembling very closely those of *Macrotaeniopteris magnifolia* (Rogers) Schimper as described and figured by Professor Fontaine in his Monograph on the Older Mesozoic Flora of Virginia, p. 18, pl. 4, figs. 1 and 1a. Two scars are seen in succession on the rachis of *T. newberriana*, pl. 1, figs. 1 and 1a. Professor Fontaine's description is taken from the depression, while in this specimen the scars project. The counter impression in wax seems to agree in every particular with his description of "elliptical depressions surrounded by a raised line, which, sweeping sharply around the ends of the depressions, continues double until a divergence takes place to embrace the next depression." Near the apex of the same specimen a third scar occurs on the middle of the rachis. Another fragment of this species, figure 2, plate IV, has two scars of the ordinary size on the midrib and a third smaller one between these two and at the side on the lamina, about one-half mm. from the midrib. The scars on *T. coriacea* are very distinctly marked. Figure 1, plate III, shows a string of them on the rachis very suggestive of Fontaine's figure. Two other specimens have a plainly marked row of scars on the rachis. The scars have no regularity of size, distance apart, or position on the rachis. In this respect they resemble Rogers' original description for those of *Macrotaeniopteris magnifolia* in which he says that the scars are placed at unequal intervals, and at rather varying distances from the midrib, and not unfrequently on the midrib itself.

A comparison of the scars born on the rachises of the two species on which they occur has failed to bring out any constant differences between them in arrangement, structure or position. They are of various sizes, from very small, one-half mm. or less, to five mm. long, about one mm. wide. The shape is seemingly constant, elliptical with the longest axis parallel to the rachis. The depressed space around the scar, "raised line" of Prof. Fontaine's description of the counter depression, is always present, sometimes comparatively broad and well marked.

Professors Rogers and Fontaine regarded the scars of *Macrotaeniopteris magnifolia* as probably the bases of sori. But their

presence on another genus, *Taeniopteris*, with additional evidence of their irregularity of arrangement, size, distance apart, and their position on the rachis—an unusual place for fern fructification—all argue strongly against such a conclusion. But there is more satisfactory evidence at hand that the scars can not have anything to do with fructification. A specimen of *Glenopteris splendens* Sellards, from the same locality, has an identical scar on the rachis, as noted in the description of that species, Kans. Univ. Quart., Vol. IX, No. 3, p. 184. A second scar occurs on the rachis of another specimen of the same genus, the species scarcely determinable, but probably the same. *Glenopteris* is a very different genus from *Taeniopteris* and can hardly be thought of as having the same fructification.

The presence of the scar on three genera and several species indicates that they are not the result of any accidental injury to the plant. It is difficult to make out with any degree of certainty what they are. They resemble some fungi rather closely. The possibility that they may be the result of pathological growth due to the sting of an insect naturally suggests itself and, indeed, seems very possible.

Figure 2, plate II, shows another set of markings, this time entirely on the lamina. They are elongate, or ovate-elongate, with the long axis parallel to the nerves, of varying size from very small to 5 or 6 mm., close or distant, project sensibly from the frond, usually with the carbonaceous layer rubbed off of the top. Some of the smaller ones are uninjured, and seem to show an elevated border with a depressed center. These scars are very suggestive of the work of the fungi.

The scars have an added interest because of their resemblance to scars on the type specimens of *Taeniopteris newberriana* from West Virginia, which Professors Fontaine andI. C. White regard as the basis of the sori. In the West Virginia specimens the scars are placed in a single row along each side of the midrib, and the frond is divided into segments by deep obtuse sinuses. Nothing of the segmented character has been observed on our specimens, and the large scars are more commonly on the midrib. These authors, however, compare the scars to those on *Macrotaeniopteris magnifolia* to which ours are very closely related. They say, Permian Flora, p. 93, "*Macrotaeniopteria rogersi* Schimper of the Richmond coal field, contains, on specimens in our possession, elliptical depressions strikingly like the depressions seen on this plant, and shown on plate XXXIV, figure 3. In the specimen from the Richmond coal the depressions are larger, and are

placed in one row *on* the midrib. Professor Wm. B. Rogers, however, in his description of the plant, says that they often occur in two rows, one on each side of the midrib." It cannot be affirmed that the scars on our specimens are the same as those on Fontaine and White's specimens, but it would seem from their relations that they are at least of the same nature, and probably have no connection with fructification.

Dr. David White has had the very great kindness to look over the manuscript and illustrations of this genus, except figure 1a, plate I, which has been added. Dr. White gives it as his opinion that the rachial pits are fungi, and suggests a cómparison with the genus *Rosellinites* Pot.

The comparison to insect stings was sugested to me originally by the close resemblance of the scars to the stings on the common *Amorpha fructicosa* (false indigo), said to be made by some of the orthopteroid insects, a supposition which the more recently discovered presence, among the plants, of two well preserved orthopterous insects may be taken to strengthen. The scars on this shrub are certainly similar in arrangement and shape to those on the fern rachises, although somewhat larger. The resemblance may of course be entirely superficial.

The suggested comparison with fungi is good, although I am inclined to think the comparison closer with the genus *Hysterites* than with *Rosellinites*. Quite recently I have found on a fragment of *Cordaites* from University Hill, Lawrence shales, Lawrence, a fungus related by its form, position, and the host on which it is borne, to some species of *Hysterites*, as *H. cordaites*, and at the same time so similar to the objects in hand as to suggest a close relation. A close examination of the rachial pits reveals the presence on two of them of elongate depressions at the center suggesting the cleft in the living genus *Hysterium*—to which *Hysterites* is compared—or the related *Hysteriographium*. This character is represented in the detailed figure 1a, plate I. If this figure had been made at the time Dr. White saw the plate, I am inclined to think he would have suggested *Hysterites* as well as *Rosellinites*, or possibly instead of that genus. The type species of *Rosellinites*, *R. beyschlagii* Pot., as described and figured by the author, Flora des Roth., p. 27, plate I, figure 8, is irregular in shape, varying from circular to elliptical or egg-shaped, running together in irregularly formed masses; the scars on the fern rachises are symmetrically elliptical, and do not show the various irregular enlargements seen on *Rosellinites beyschlagii*.

These scars merit a more careful and extensive comparison with living and fossil forms than I have been able to give them. Amopg a few living fungi with which I have had the opportunity of making comparison, *Hystertiographium vulvatum*, kindly loaned me by Professor Barber, may be mentioned as having conceptacles shaped like the scars in question, with a central cleft that might be considered homologous with the depressed center of the scars. I have not noticed anything in the living species that seems to represent the depressed canal, "raised line," in Professor Fontaine's description.

On the Group of 216 Collineations in the Plane.

BY H. B. NEWSON.

§1. Introduction.

The group of 216 collineations in the plane was discovered by C. Jordan and treated by him in *Crelle, Band* 84, pp. 89-215; and discussed again by him in *Atti della Reale Accademia di Napoli, Tome* 8 (1879). This group has been further studied by Maschke in *Math. Annalen, Band* 33, pp. 324-330. This paper by Maschke is the standard reference on the subject.

The object of the present paper is to study the geometric properties of the group and its sub-groups with respect to a pencil of cubic curves through nine points of inflection; to determine the types of collineations entering into the group; to determine the order of each transformation and the position of the invariant triangle in each case.

§2. The Pencil of Cubics, $x^3+y^3+z^3+6mxyz=0$.

The theory of the group of 216 collineations in the plane is so intimately related to the theory of a pencil of cubics through nine points of inflection, that a résumé of certain properties of such a pencil is a necessary preliminary to the study of the group.

If m is a variable parameter, the equation,

$$x^3+y^3+z^3+6mxyz=0, \qquad (1)$$

represents ∞^1 cubics having nine points of intersection which are points of inflection on all cubics of the pencil.

From any point P on a cubic C four tangents can be drawn to C exclusive of the tangent at P. The cross-ratio of these tangents is constant for all points on the curve and is different for different curves of the pencil. This cross-ratio k is absolutely unaltered by projection, and hence two cubics can not be linearly transformed into each other unless they have the same absolute invariant k. The value of k in terms of m is given by the equation

$$\frac{(k^2-k+1)^3}{[(k+1)(k-2)(k-\frac{1}{2})]^2}=\frac{64m^3(m^3-1)^3}{(8m^6+20m^3-1)^2}=\phi(k). \qquad (2)$$

For any given value of k this is an equation of the twelfth degree in m; hence there are twelve cubics in the pencil, all having the same cross-ratio k. Given any cubic of the pencil it can be projected into itself and into only eleven other cubics of the pencil.

Expanding equation (2) we have

$$64(1-\phi)m^{12}-64(3+5\phi)m^9+192(1-2\phi)m^6-8(8-5\phi)m^3-\phi=0. \qquad (3)$$

The solution of this equation depends upon that of a quartic; its roots may be written m_i, αm_i, $\alpha^2 m_i$, $(i=1, 2, 3, 4)$ and $\alpha^3=1$. Hence our set of twelve is composed of four sub-divisions of three cubics each.

For certain special values of k our system of twelve cubics reduces to a smaller number. Thus when $k=-\alpha$ or $-\alpha^2$ we have $m=0, 1, \alpha, \alpha^2$; here the three cubics of each sub-division have coincided and our twelve cubics have reduced to four. These four cubics are called the *equianharmonic* cubics of the pencil. Their equations are

$$\begin{aligned}
&(1)\quad x^3+y^3+z^3=0,\\
&(2)\quad x^3+y^3+z^3+6xyz=0,\\
&(3)\quad x^3+y^3+z^3+6\alpha xyz=0,\\
&(4)\quad x^3+y^3+z^3+6\alpha^2 xyz=0.
\end{aligned} \qquad (4)$$

When $k=-1$, 2, $\frac{1}{2}$, the twelve values of m reduce to six; viz:

$$m=\frac{-1\pm\sqrt{3}}{2},\ \alpha\left(\frac{-1\pm\sqrt{3}}{2}\right),\ \alpha^2\left(\frac{-1\pm\sqrt{3}}{2}\right). \qquad (4a)$$

These six cubics are called the *harmonic* cubics of the pencil.

When $k=1$, 0, ∞, we have $m=\infty$, $-\frac{1}{2}$, $-\frac{1}{2}\alpha$, $-\frac{1}{2}\alpha^2$. These four cubics are characterized by the common property that each of them breaks up into three linear factors. Thus

$$\begin{aligned}
&(1)\quad xyz=0,\\
&(2)\quad x^3+y^3+z^3-3xyz\equiv(x+y+z)(x+\alpha y+\alpha^2 z)(x+\alpha^2 y+\alpha z)=0,\\
&(3)\quad x^3+y^3+z^3-3\alpha xyz\equiv(\alpha x+y+z)(x+\alpha y+z)(x+y+\alpha z)=0,\\
&(4)\quad x^3+y^3+z^3-3\alpha^2 xyz\equiv(\alpha^2 x+y+z)(x+\alpha^2 y+z)(x+y+\alpha^2 z)=0.
\end{aligned} \qquad (5)$$

Each of these degenerate cubics consists of three straight lines which form a triangle, one of them being the triangle of reference. They are the inflectional triangles of the pencil of cubics.

Between these four degenerate cubics and the four equianharmonic cubics there exists a very simple relation. Each equianharmonic cubic is gotten by taking the sum of the cubes of the linear factors of the corresponding degenerate cubic. Thus, for example, we have

$$3(x^3+y^3+z^3+6xyz)=(x+y+z)^3+(x+\alpha y+\alpha^2 z)^3 + (x+\alpha^2 y+\alpha x)^3. \qquad (6)$$

The coördinates of the nine points of inflection of the pencil of cubics is best found by eliminating between $x^3+y^3+z^3=0$ and $xyz=0$. They are as follows:

$$\begin{array}{llllll} (1) & 0,\ 1,\ -1; & (2) & 0,\ \alpha,\ -1; & (3) & 0,\ 1,\ -\alpha; \\ (4) & -1,\ 0,\ 1; & (5) & -1,\ 0,\ \alpha; & (6) & -\alpha,\ 0,\ 1; \\ (7) & 1,\ -1,\ 0; & (8) & \alpha,\ -1,\ 0; & (9) & 1,\ -\alpha,\ 0. \end{array} \qquad (7)$$

The harmonic polars of these nine points of inflection are given by the following equations:

$$\begin{array}{llllll} (1) & y-z=0, & (2) & \alpha^2 y-z=0, & (3) & \alpha y-z=0, \\ (4) & z-x=0, & (5) & \alpha^2 z-x=0, & (6) & \alpha z-x=0, \\ (7) & x-y=0, & (8) & \alpha^2 x-y=0, & (9) & \alpha x-y=0. \end{array} \qquad (8)$$

Each of the inflectional triangles intersect the pencil of cubics in the same nine points; hence the nine points of inflection lie three by three on twelve right lines. Each harmonic polar passes through a vertex of each of the four inflectional triangles; hence the twelve vertices of the inflectional triangles lie four by four on nine right lines.

The vertices of the four inflectional triangles may be designated by A_i, B_i, C_i, $(i=1, 2, 3, 4)$. The coördinates of these twelve points are as follows:

$$1.\begin{cases} 1,\ 0,\ 0, \\ 0,\ 1,\ 0, \\ 0,\ 0,\ 1. \end{cases} \quad 2.\begin{cases} 1,\ 1,\ 1, \\ 1,\ \alpha^2,\ \alpha, \\ 1,\ \alpha,\ \alpha^2. \end{cases} \quad 3.\begin{cases} \alpha^2,\ 1,\ 1, \\ 1,\ \alpha^2,\ 1, \\ 1,\ 1,\ \alpha^2. \end{cases} \quad 4.\begin{cases} \alpha,\ 1,\ 1, \\ 1,\ \alpha,\ 1, \\ 1,\ 1,\ \alpha, \end{cases} \qquad (9)$$

§3. The Group G_{216}.

It is a well known fact* in the theory of plane cubics that every non-singular cubic C can be projectively transformed into itself in eighteen different ways and that these eighteen collineations form a group G_{18} which also transforms into itself every cubic of the pencil $C+6kH=0$. We shall investigate this group in detail in the next section, but here we wish to make use of the generally known fact.

It was shown in §2 that a cubic C is one of a set of twelve cubics C_i ($i=1 \ldots . 12$) which can be projectively transformed into one another. Since each cubic of the set may be transformed into itself in eighteen different ways, we infer that each cubic of the set may also be transformed into any other cubic of the set in eighteen different ways. If this be true, there are 12.18 transformations which leave invariant the set of twelve cubics. These 216 collineations form a group G_{216}.

The configuration of four equianharmonic cubics, four degenerate cubics and six harmonic cubics—shown in §2—is analogous to a tetrahedron which has four vertices, four faces and six edges. Accordingly the structure of the group G_{216} is analogous to the structure of the tetrahedron group G_{12}, which we assume as known. To the identical substitution in G_{12} corresponds the group G_{18} in G_{216}. To the four sub-groups G_3 in G_{12}, each leaving a vertex and opposite face invariant, correspond four sub-groups G_{54} in G_{216}, each leaving invariant a degenerate and an equianharmonic cubic. To the three sub-groups G_2 in G_{12}, each leaving invariant a pair of opposite edges, correspond three sub-groups G_{36} in G_{216}, each leaving invariant a pair of conjugate harmonic cubics. To the invariant sub-group G_4 in G_{12} corresponds an invariant sub-group G_{72} in G_{216}.

We shall now take up the study of these sub-groups of G_{216} and examine into their structure and determine the properties of the individual transformations found in them. We shall determine in particular the order and the invariant triangle of each transformation occurring in G_{216}.

§4. The Group G_{18}.

The harmonic polar l of a point of inflection I is characterized by the following property: Every line through I cuts the cubic C in two other points P and Q and l in L. The cross-ratio of

*Clebsch, Vorlesungen ueber Geometrie, I, S. 512.

(ILPR)=—1. If, therefore, we set up a perspective transformation of order 2 having I for its vertex and l for its axis, it will transform C into itself.

Take the point of inflection (0, 1, —1) and its harmonic polar $y-z=0$; choose any two points on this line as (0, 1, 1) and (1, 1, 1). The single cross-ratio of this transformation is $k=-1$. The equations of the transformation may be written down by means of the following formulas:*

$$\rho x_1=\begin{vmatrix} x & y & z & 0 \\ A & B & C & A \\ A_1 & B_1 & C_1 & kA_1 \\ A_2 & B_2 & C_2 & k'A_2 \end{vmatrix}; \quad \rho y_1=\begin{vmatrix} x & y & z & 0 \\ A & B & C & B \\ A_1 & B_1 & C_1 & kB_1 \\ A_2 & B_2 & C_2 & k'B_2 \end{vmatrix};$$

$$\rho z_1=\begin{vmatrix} x & y & z & 0 \\ A & B & C & C \\ A_1 & B_1 & C_1 & kC_1 \\ A_2 & B_2 & C_2 & k'C_2 \end{vmatrix}. \qquad (10)$$

Substituting in these formulas the above values of A, B, etc., and making both k and k′ equal to —1, these reduce to

$$x_1=x, \quad y_1=z, \quad z_1=y. \qquad (11)$$

There are nine transformations, one for each point of inflection; they may all be written down by means of the same general formula. Three of them will be real and six imaginary. If we make any one of these nine substitutions in the equation of the pencil of cubics, we find that every cubic of the pencil is transformed into itself.

Again, let us take a transformation whose invariant triangle is the triangle of reference and whose cross-ratios are k and k′. Writing down the equations of this transformation by means of formulas (10) we find $\begin{cases} x_1=x \\ y_1=ky \\ z_1=k'z. \end{cases}$ Making this substitution in the equation of the pencil of cubics we get

$$x^3+k^3y^3+k'^3z^3+6mkk'xyz=0.$$

*K. U. Quarterly, vol. viii, pp. 45-66. I have recently found that these formulas were previously given in nearly the same form by Prof. Gabriele Torrelli in the *Rendiconti di Circolo Matematico di Palermo, Tome* viii, pp. 41-54.

Every cubic of the pencil will be transformed into itself when $k^3=1$, $k'^3=1$, and $kk'=1$. These relations are satisfied by $k=\alpha$ and $k'=\alpha^2$ or by $k=\alpha^2$ and $k'=\alpha$. Thus we have two transformations

$$\begin{array}{lcl} x_1=x & & x_1=x \\ y_1=\alpha y & \text{and} & y_1=\alpha^2 y \\ z_1=\alpha^2 z & & z_1=\alpha z \end{array} \qquad (12)$$

of this kind which transform every cubic of the pencil into itself. These are a pair of inverse transformations and each of period 3.

In like manner it may be shown that each of the other inflectional triangles is the invariant triangle of a pair of transformations of period 3, such that they transform every cubic of the pencil into itself. In this way we find eight transformations of this variety. The equations of these eight transformations may be written down by means of formulas (10), making use of the values given in (9). These equations are as follows, numbered according to the triangles:

$$1.\left\{\begin{array}{ll} x_1=x, & x \\ y_1=\alpha y, & \alpha^2 y; \\ z_1=\alpha^2 z, & \alpha z \end{array}\right. \quad 2.\left\{\begin{array}{ll} y, & z \\ z, & x; \\ x, & y \end{array}\right. \quad 3.\left\{\begin{array}{ll} y, & z \\ \alpha z, & \alpha^2 x; \\ \alpha^2 x, & \alpha y \end{array}\right. \quad 4.\left\{\begin{array}{ll} y, & z \\ \alpha^2 z, & \alpha x\,. \\ \alpha x, & \alpha^2 y \end{array}\right. \qquad (13)$$

These eight transformations, together with the nine perspective transformations given above, and the identical transformation constitute a group G_{18}, every transformation in which transforms every cubic of the pencil into itself. The fact that these eighteen transformations form a group may be verified by applying the test of forming all possible resultants. There are no other transformations possessing this property,

It is evident from the character of the transformations contained in G_{18} that the group contains four cyclic sub-groups of order 3 and nine cyclic sub groups of order 2. G_{18} also contains a subgroup G_6 of order 6 and one G_9 of order 9. These are given as follows:

$$G_6=\begin{array}{l} x_1=x,\ x,\ z,\ y,\ y,\ z, \\ y_1=y,\ z,\ y,\ x,\ z,\ x, \\ z_1=z,\ y,\ x,\ z,\ x,\ y, \end{array}\equiv G_3+3G_2. \qquad (14)$$

All transformations of this group are real; one is of order 1, three of order 2 and two of order 3. The group G_9 is as follows:

$$G_9=\begin{array}{l} x_1=x,\ x,\ x,\ y,\ z,\ y,\ z,\ y,\ z, \\ y_1=y,\ \alpha y,\ \alpha^2 y,\ z,\ x,\ \alpha z,\ \alpha^2 x,\ \alpha^2 z,\ \alpha x. \\ z_1=z,\ \alpha^2 z,\ \alpha z,\ x,\ y,\ \alpha^2 x,\ \alpha y,\ \alpha x,\ \alpha^2 y, \end{array}\equiv 4G_3.$$

This group contains one transformation of order 1 and eight of order 3.

Theorem 1.—Every transformation of the group G_{18} transforms into itself every cubic of the pencil $C+6mH=0$, where H is the Hessian of C; G_{18} contains (1) one transformation of order 1, (2) nine transformations of order 2, (3) eight transformations of order 3. These are as follows:

(1). The identical transformation.

(2). Each of the nine points of inflection and its corresponding harmonic polar are the vertex and axis respectively of a perspective transformation of order 2.

(3). Each of the four inflectional triangles is the invariant triangle of a pair of inverse transformations of type I and order 3.

§5. The Group G_{54} (1).

As remarked above, the group G_{216} contains four sub-groups $G_{54}(i)$, $(i=1, 2, 3, 4)$, one for each equianharmonic cubic. We begin with the most simple one, which has for invariant figure the triangle of reference $xyz=0$ and the cubic $x^3+y^3+z^3=0$. This group G_{54} contains, of course, the eighteen transformations of G_{18} and hence thirty-six other transformations which we must investigate.

Since $x^3+y^3+z^3$ is an invariant of our group it is evident that the group contains all transformations of the form of those contained in G_{18}, where x, y, and z are interchanged in all possible ways and combined with the coefficients α, α^2, α^3, in all possible ways which give rise to different transformations. We can readily write down a table of all such transformations, and we find that it contains just fifty-four transformations and no more. These, then, constitute the group G_{54}. The table is as follows, in which the number placed above each formula indicates the order of the transformation:

I	3	3	3	3	3	3	3	3
$x_1=x$,	x,	x,	α^2x,	αx,	x,	x,	x,	x
$y_1=y$,	αy,	α^2y,	y,	y,	α^2y,	αy,	y,	y
$z_1=z$,	α^2y,	αz,	z,	z,	z,	z,	α^2z,	αz

2	2	2	6	6	6	6	6	6
$x_1=x$,	x,	x,	α^2x,	αx,	x,	x,	x,	x
$y_1=z$,	αz,	α^2z,	z,	z,	α^2z,	αz,	z,	z
$z_1=y$,	α^2y,	αy,	y,	y,	y,	y,	α^2y,	αy

2	2	2	6	6	6	6	6	6
$x_1=z$,	z,	z,	α^2z,	αz,	z,	z,	z,	z
$y_1=y$,	αy,	α^2y,	y,	y,	α^2y,	αy,	y,	y
$z_1=x$,	α^2x,	αx,	x,	x,	x,	x,	α^2x,	αx

2	2	2	6	6	6	6	6	6
$x_1=y$,	y,	y,	α^2y,	αy,	y,	y,	y,	y
$y_1=x$,	αx,	α^2x,	x,	x,	α^2x,	αx,	x,	x
$z_1=z$,	α^2z,	αz,	z,	z,	z,	z,	α^2z,	αz

3	3	3	3	3	3	3	3	3
$x_1=y$,	y,	y,	α^2y,	αy,	y,	y,	y,	y
$y_1=z$,	αz,	α^2z,	z,	z,	α^2z,	αz,	z,	z
$z_1=x$,	α^2x,	αx,	x,	x,	x,	x,	α^2x,	αx

3	3	3	3	3	3	3	3	3
$x_1=z$,	z,	z,	α^2z,	αz,	z,	z,	z,	z
$y_1=x$,	αx,	α^2x,	x,	x,	α^2x,	αx,	x,	x
$z_1=y$,	α^2y,	αy,	y,	y,	y,	y,	α^2y,	αy

We observe that the eighteen transformations given in the first three columns of the table form the group G_{18} discussed above. We shall find that of the thirty-six remaining transformations eighteen are of order 3 and eighteen of order 6; we shall further find that there are two distinct varieties of these transformations of order 3.

We first consider the last six transformations of the first row of the table. Take first the transformation $\left\{\begin{matrix} x_1=\alpha^2 x \\ y_1=y; \\ z_1=z \end{matrix}\right.$ it evidently leaves invariant each side of the triangle of reference. It may also be written in the form $\left\{\begin{matrix} x \\ \alpha y, \\ \alpha z \end{matrix}\right.$ from which we see that the cross-ratios along the sides y and z are each equal to α and that along x is unity. The transformation is, therefore, of type IV, the axis of invariant points being $x=0$; and the single invariant point or vertex being the point (1, 0, 0), the opposite vertex of the invariant triangle. This transformation is evidently of order 3; its inverse is also its square viz: $\left\{\begin{matrix} \alpha x \\ y. \\ z \end{matrix}\right.$ In like manner it is seen that the two inverse transformations $\left\{\begin{matrix} x, \\ \alpha^2 y, \\ z, \end{matrix}\right.$ $\left\{\begin{matrix} x \\ \alpha y, \\ z \end{matrix}\right.$ are also of type IV and of order 3, the axis being $y=0$ and the vertex being the opposite vertex of the triangle of reference. A similar results holds also for the pair $\left\{\begin{matrix} x, \\ y, \\ \alpha^2 z, \end{matrix}\right.$ $\left\{\begin{matrix} x \\ y. \\ \alpha z \end{matrix}\right.$ We have thus found six perspective transformations, each of order 3; these are easily identified with the last six transformations of the first row of the table.

We next consider the fourth transformation of the second row of the table, viz: $\left\{\begin{matrix} \alpha^2 x \\ z. \\ y \end{matrix}\right.$ Calling it T we have,

$$T=\begin{matrix} \alpha^2 x, \\ z, \\ y \end{matrix}\quad T^2=\begin{matrix} \alpha x, \\ y, \\ z \end{matrix}\quad T^3=\begin{matrix} x, \\ z, \\ y \end{matrix}\quad T^4=\begin{matrix} \alpha^2 x, \\ y, \\ z \end{matrix}\quad T^5=\begin{matrix} \alpha x, \\ z, \\ y \end{matrix}\quad T^6=\begin{matrix} x, \\ y, \\ z \end{matrix}=1. \qquad (15)$$

The transformation T is therefore of order 6; T^2 and T^4 are of order 3 and T^3 is of order 2. T^2, T^3, T^4 have been studied above and their characteristics are already known.

T and its inverse T^5 are now to be investigated. The invariant

triangle of T is found by putting x_1, y_1, and z_1 equal to x, y, and z respectively. We thus find that the sides of the invariant triangle are $x=0$, $y-z=0$, and $y+z=0$. Solving these equations we find the vertices of the invariant triangle to be $A=(0,1,-1)$, $B=(1,0,0)$, $C=(0,1,1)$. Thus one vertex, A, of the invariant triangle is a point of inflection and the opposite side is its harmonic polar. One vertex of the inflectional triangle, $xyz=0$, lies on this harmonic polar, viz: $(1,0,0)$; the opposite side, $x=0$, completes the invariant triangle. The position of the invariant triangle is thus completely determined.

The cross-ratios along the sides AB, BC, CA of the invariant triangle are respectively $-\alpha^2$, α, -1. This may be verified by writing down the cross-ratios of the first six powers of T, assuming T to be given by $-\alpha^2$, α, -1. Thus

$$\begin{array}{lll} \text{AB} & \text{BC} & \text{CA} \\ T=-\alpha^2, & \alpha, & -1; \\ T^2=\alpha, & \alpha^2, & 1; \\ T^3=-1, & 1, & -1; \\ T^4=\alpha^2, & \alpha, & 1; \\ T^5=-\alpha, & \alpha^2, & -1; \\ T^6=1, & 1, & 1. \end{array} \qquad (16)$$

T^2 and T^4 are thus shown to be transformations of type IV and order 3, having an identical transformation along the side CA. T^3 is of type IV and order 2, having an identical transformation along BC.

The transformation T may be written down by means of formulas (10) as follows:

$$\rho x_1=\begin{vmatrix} x & y & z & 0 \\ 0 & 1 & -1 & 0 \\ 1 & 0 & 0 & -\alpha^2 \\ 0 & 1 & 1 & 0 \end{vmatrix}; \quad \rho y_1=\begin{vmatrix} x & y & z & 0 \\ 0 & 1 & -1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & -1 \end{vmatrix}$$

$$\rho z_1=\begin{vmatrix} x & y & z & 0 \\ 0 & 1 & -1 & -1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & -1 \end{vmatrix}.$$

Hence we have $\rho x_1 = -2a^2x$, $\rho y_1 = -2z$, $\rho z_1 = -2y$; or $\left\{\begin{array}{l} x_1 = a^2x \\ y_1 = z. \\ z_1 = y \end{array}\right.$

We have seen how the two transformations T and T^5 are related to the point of inflection A. In like manner there are two transformations of order 6 related in the same way to each of the nine points of inflection. We have thus eighteen transformations of order 6. Their equations may readily be found from their known invariant triangles by means of formulas (10). These eighteen transformations are all given in rows 2, 3, and 4, of the table.

There still remain to be investigated the twelve transformations found in the last six places in rows 5 and 6. Take, for example, $\left\{\begin{array}{l} x_1 = a^2y \\ y_1 = z \\ z_1 = x \end{array}\right.$ and denote it by S. Taking the powers of S we find

$$S = \begin{array}{c} a^2y, \\ z, \\ x, \end{array} \quad S^2 = \begin{array}{c} a^2z, \\ x, \\ a^2y, \end{array} \quad \text{or} \quad \begin{array}{c} z, \\ ax, \\ y, \end{array} \quad S^3 = \begin{array}{c} a^2x \\ a^2y = 1, \\ a^2z \end{array}$$

S and S^2 are thus of order 3. We proceed to find the vertices of the invariant triangle of S by solving the equations $\begin{array}{l} x = a^2y \\ y = z. \\ z = x \end{array}$ We find the coördinates of the invariant points to be $A = (1, \lambda^8, \lambda^4)$, $B = (1, \lambda^5, \lambda^7)$, $C = (1, \lambda^2, \lambda)$, where λ is an irreducible 9th root of unity. Since $1 + \lambda^6 + \lambda^3 = 0$, it follows that these points all lie on the cubic $x^3 + y^3 + z^3 = 0$. It may easily be verified that the tangent to this cubic A cuts the cubic again at B; the tangent at B cuts again at C; and the tangent at C cuts the cubic again at A. Hence the cubic is both inscribed and circumscribed to the triangle ABC.

In order to determine the number of such triangles both inscribing and circumscribing the cubic, $x^3 + y^3 + z^3 = 0$, we write down the tangent at the point x', y', z'; viz: $xx'^2 + yy'^2 + zz'^2 = 0$. If this passes through the point x'', y'', z'', we have $x''x'^2 + y''y'^2 + z''z'^2 = 0$; and similar results for the other points. Thus we have six equations, viz:

$$\begin{array}{ll} x''x'^2 + y''y'^2 + z''z'^2 = 0, & x'^3 + y'^3 + z'^3 = 0, \\ x'''x''^2 + y'''y''^2 + z'''z''^2 = 0, & x''^3 + y''^3 + z''^3 = 0, \\ x'x'''^2 + y'y'''^2 + z'z'''^2 = 0, & x'''^3 + y'''^3 + z'''^3 = 0, \end{array} \qquad (17)$$

from which to determine the coördinates of the invariant points. These equations have eighteen solutions; hence there are six such triangles. The coördinates of these eighteen points are as follows:

$$\left\{\begin{matrix} 1, & \lambda^8, & \lambda^4 \\ 1, & \lambda^5, & \lambda^7 \\ 1, & \lambda^2, & \lambda \end{matrix}\right\}, \quad \left\{\begin{matrix} 1, & \lambda^7, & \lambda^8 \\ 1, & \lambda, & \lambda^5 \\ 1, & \lambda^4, & \lambda^2 \end{matrix}\right\}, \quad \left\{\begin{matrix} 1, & \lambda^5, & \lambda^4 \\ 1, & \lambda^2, & \lambda^7 \\ 1, & \lambda^8, & \lambda \end{matrix}\right\},$$

$$\left\{\begin{matrix} 1, & \lambda, & \lambda^8 \\ 1, & \lambda^4, & \lambda^5 \\ 1, & \lambda^7, & \lambda^2 \end{matrix}\right\}, \quad \left\{\begin{matrix} 1, & \lambda^5, & \lambda \\ 1, & \lambda^2, & \lambda^4 \\ 1, & \lambda^8, & \lambda^7 \end{matrix}\right\}, \quad \left\{\begin{matrix} 1, & \lambda, & \lambda^2 \\ 1, & \lambda^4, & \lambda^8 \\ 1, & \lambda^7, & \lambda^5 \end{matrix}\right\}.$$

Each of these triangles is the invariant triangle of two transformations of order 3. Thus we have twelve transformations of this variety. The equations of these twelve transformations may be written down by means of formulas (10). We give one example:

$$\rho x_1 = \begin{vmatrix} x & y & z & 0 \\ 1 & \lambda & \lambda^2 & 1 \\ 1 & \lambda^7 & \lambda^5 & a \\ 1 & \lambda^4 & \lambda^8 & a^2 \end{vmatrix}, \quad \rho y_1 = \begin{vmatrix} x & y & z & 0 \\ 1 & \lambda & \lambda^2 & \lambda \\ 1 & \lambda^7 & \lambda^5 & \lambda^7 a \\ 1 & \lambda^4 & \lambda^8 & \lambda^4 a^2 \end{vmatrix},$$

$$\rho z_1 = \begin{vmatrix} x & y & z & 0 \\ 1 & \lambda & \lambda^2 & \lambda \\ 1 & \lambda^7 & \lambda^5 & \lambda^5 a \\ 1 & \lambda^4 & \lambda^8 & \lambda^8 a^2 \end{vmatrix}.$$

These reduce to $\rho x_1 = 3\lambda(a - a^2)z$, $\rho y_1 = 3\lambda^4(a - a^2)x$, $\rho z_1 = 3\lambda^4(a - a^2)y$

or $\left\{\begin{matrix} x_1 = a^2 z \\ y_1 = x. \\ z_1 = y \end{matrix}\right.$ The eleven others are obtained in like manner.

The following sub-groups of G_{54} may be noted: G_{18} is an invariant sub-group; the nine transformations in the first row of the table form a group G_9. This group leaves invariant all three sides of the triangle $xyz = 0$. The first and second rows of the table constitute a group xG_{18}, which leaves invariant the side $x = 0$. In like manner the first and third rows and the first and fourth rows form groups yG_{18} and zG_{18}, whose invariants are respectively $y = 0$ and $z = 0$. Rows 1, 5 and 6 form a group G_{27}.

§6. The Groups $G_{54}(i)$ $(i = 2, 3, 4)$.

Having determined the structure and properties of the group G_{54} (1) we can readily find from this the structure and properties of its equivalent groups $G_{54}(i)$ $(i = 2, 3, 4)$. We shall first confine our attention to the group $G_{54}(2)$.

We observe that the eighteen transformations given in the first three columns of the table form the group G_{18} discussed above. We shall find that of the thirty-six remaining transformations eighteen are of order 3 and eighteen of order 6; we shall further find that there are two distinct varieties of these transformations of order 3.

We first consider the last six transformations of the first row of the table. Take first the transformation $\begin{cases} x_1 = a^2x \\ y_1 = y; \\ z_1 = z \end{cases}$ it evidently leaves invariant each side of the triangle of reference. It may also be written in the form $\begin{cases} x \\ ay, \\ az \end{cases}$ from which we see that the cross-ratios along the sides y and z are each equal to a and that along x is unity. The transformation is, therefore, of type IV, the axis of invariant points being $x=0$; and the single invariant point or vertex being the point (1, 0, 0), the opposite vertex of the invariant triangle. This transformation is evidently of order 3; its inverse is also its square viz: $\begin{cases} ax \\ y. \\ z \end{cases}$ In like manner it is seen that the two inverse transformations $\begin{cases} x, \\ a^2y, \\ z, \end{cases}$ $\begin{cases} x \\ ay, \\ z \end{cases}$ are also of type IV and of order 3, the axis being $y=0$ and the vertex being the opposite vertex of the triangle of reference. A similar results holds also for the pair $\begin{cases} x, \\ y, \\ a^2z, \end{cases}$ $\begin{cases} x \\ y. \\ az \end{cases}$ We have thus found six perspective transformations, each of order 3; these are easily identified with the last six transformations of the first row of the table.

We next consider the fourth transformation of the second row of the table, viz: $\begin{cases} a^2x \\ z. \\ y \end{cases}$ Calling it T we have,

$$T = \begin{matrix} a^2x, \\ z, \\ y \end{matrix} \quad T^2 = \begin{matrix} ax, \\ y, \\ z \end{matrix} \quad T^3 = \begin{matrix} x, \\ z, \\ y \end{matrix} \quad T^4 = \begin{matrix} a^2x, \\ y, \\ z \end{matrix} \quad T^5 = \begin{matrix} ax, \\ z, \\ y \end{matrix} \quad T^6 = \begin{matrix} x, \\ y, \\ z \end{matrix} = 1. \tag{15}$$

The transformation T is therefore of order 6; T^2 and T^4 are of order 3 and T^3 is of order 2. T^2, T^3, T^4 have been studied above and their characteristics are already known.

T and its inverse T^5 are now to be investigated. The invariant

$$\left\{\begin{matrix} 1, & \lambda^8, & \lambda^4 \\ 1, & \lambda^5, & \lambda^7 \\ 1, & \lambda^2, & \lambda \end{matrix}\right\}, \quad \left\{\begin{matrix} 1, & \lambda^7, & \lambda^8 \\ 1, & \lambda, & \lambda^5 \\ 1, & \lambda^4, & \lambda^2 \end{matrix}\right\}, \quad \left\{\begin{matrix} 1, & \lambda^5, & \lambda^4 \\ 1, & \lambda^2, & \lambda^7 \\ 1, & \lambda^8, & \lambda \end{matrix}\right\},$$

$$\left\{\begin{matrix} 1, & \lambda, & \lambda^8 \\ 1, & \lambda^4, & \lambda^5 \\ 1, & \lambda^7, & \lambda^2 \end{matrix}\right\}, \quad \left\{\begin{matrix} 1, & \lambda^5, & \lambda \\ 1, & \lambda^2, & \lambda^4 \\ 1, & \lambda^8, & \lambda^7 \end{matrix}\right\}, \quad \left\{\begin{matrix} 1, & \lambda, & \lambda^2 \\ 1, & \lambda^4, & \lambda^8 \\ 1, & \lambda^7, & \lambda^5 \end{matrix}\right\}.$$

Each of these triangles is the invariant triangle of two transformations of order 3. Thus we have twelve transformations of this variety. The equations of these twelve transformations may be written down by means of formulas (10). We give one example:

$$\rho x_1 = \begin{vmatrix} x & y & z & o \\ 1 & \lambda & \lambda^2 & 1 \\ 1 & \lambda^7 & \lambda^5 & a \\ 1 & \lambda^4 & \lambda^8 & a^2 \end{vmatrix}, \quad \rho y_1 = \begin{vmatrix} x & y & z & o \\ 1 & \lambda & \lambda^2 & \lambda \\ 1 & \lambda^7 & \lambda^5 & \lambda^7 a \\ 1 & \lambda^4 & \lambda^8 & \lambda^4 a^2 \end{vmatrix},$$

$$\rho z_1 = \begin{vmatrix} x & y & z & o \\ 1 & \lambda & \lambda^2 & \lambda \\ 1 & \lambda^7 & \lambda^5 & \lambda^5 a \\ 1 & \lambda^4 & \lambda^8 & \lambda^8 a^2 \end{vmatrix}.$$

These reduce to $\rho x_1 = 3\lambda(a - a^2)z$, $\rho y_1 = 3\lambda^4(a - a^2)x$, $\rho z_1 = 3\lambda^4(a - a^2)y$

or $\left\{\begin{matrix} x_1 = a^2 z \\ y_1 = x. \\ z_1 = y \end{matrix}\right.$ The eleven others are obtained in like manner.

The following sub-groups of G_{54} may be noted: G_{18} is an invariant sub-group; the nine transformations in the first row of the table form a group G_9. This group leaves invariant all three sides of the triangle $xyz = o$. The first and second rows of the table constitute a group xG_{18}, which leaves invariant the side $x = o$. In like manner the first and third rows and the first and fourth rows form groups yG_{18} and zG_{18}, whose invariants are respectively $y = o$ and $z = o$. Rows 1, 5 and 6 form a group G_{27}.

§6. The Groups $G_{54}(i)$ $(i = 2, 3, 4)$.

Having determined the structure and properties of the group G_{54} (1) we can readily find from this the structure and properties of its equivalent groups $G_{54}(i)$ $(i = 2, 3, 4)$. We shall first confine our attention to the group $G_{54}(2)$.

We observe that the eighteen transformations given in the first three columns of the table form the group G_{18} discussed above. We shall find that of the thirty-six remaining transformations eighteen are of order 3 and eighteen of order 6; we shall further find that there are two distinct varieties of these transformations of order 3.

We first consider the last six transformations of the first row of the table. Take first the transformation $\left\{\begin{array}{l} x_1 = \alpha^2 x \\ y_1 = y; \\ z_1 = z \end{array}\right.$ it evidently leaves invariant each side of the triangle of reference. It may also be written in the form $\left\{\begin{array}{l} x \\ \alpha y, \\ \alpha z \end{array}\right.$ from which we see that the cross-ratios along the sides y and z are each equal to α and that along x is unity. The transformation is, therefore, of type IV, the axis of invariant points being $x=0$; and the single invariant point or vertex being the point (1, 0, 0), the opposite vertex of the invariant triangle. This transformation is evidently of order 3; its inverse is also its square viz: $\left\{\begin{array}{l} \alpha x \\ y. \\ z \end{array}\right.$ In like manner it is seen that the two inverse transformations $\left\{\begin{array}{l} x, \\ \alpha^2 y, \\ z, \end{array}\right.$ $\left\{\begin{array}{l} x \\ \alpha y, \\ z \end{array}\right.$ are also of type IV and of order 3, the axis being $y=0$ and the vertex being the opposite vertex of the triangle of reference. A similar results holds also for the pair $\left\{\begin{array}{l} x, \\ y, \\ \alpha^2 z, \end{array}\right.$ $\left\{\begin{array}{l} x \\ y. \\ \alpha z \end{array}\right.$ We have thus found six perspective transformations, each of order 3; these are easily identified with the last six transformations of the first row of the table.

We next consider the fourth transformation of the second row of the table, viz: $\left\{\begin{array}{l} \alpha^2 x \\ z. \\ y \end{array}\right.$ Calling it T we have,

$$T = \begin{array}{l} \alpha^2 x, \\ z, \\ y \end{array} \quad T^2 = \begin{array}{l} \alpha x, \\ y, \\ z \end{array} \quad T^3 = \begin{array}{l} x, \\ z, \\ y \end{array} \quad T^4 = \begin{array}{l} \alpha^2 x, \\ y, \\ z \end{array} \quad T^5 = \begin{array}{l} \alpha x, \\ z, \\ y \end{array} \quad T^6 = \begin{array}{l} x, \\ y, \\ z \end{array} = 1. \qquad (15)$$

The transformation T is therefore of order 6; T^2 and T^4 are of order 3 and T^3 is of order 2. T^2, T^3, T^4 have been studied above and their characteristics are already known.

T and its inverse T^5 are now to be investigated. The invariant

are the vertex and axis respectively of a pair of inverse perspective transformations of order 3.

(3). Each of the six triangles both inscribed and circumscribed to the equianharmonic cubic i is the invariant triangle of a pair of inverse transformations of type I and order 3.

(4). Each of the nine triangles, k, (k=1 . . 9), described below, is the invariant triangle of a pair of inverse transformations of type I and order 6. A point of inflection k and its corresponding harmonic polar form one vertex and the opposite side of the invariant triangle; that vertex of the inflectional triangle i which is on this harmonic polar and that side of the triangle i which passes through the point of inflection k complete the invariant triangle.

§7. The Group G_{36} (1).

It was pointed out in §2 that the group G_{216} contains three equivalent sub-groups $G_{36}(j)$ $(j=1,2,3)$, one corresponding to each pair of harmonic cubics in the pencil $C+6kH=0$. We first take up the group G_{36} (1), which leaves invariant the pair of cubics given by $m=\frac{-1\pm\sqrt{3}}{2}$ in the pencil $x^3+y^3z^3+6mxyz=0$.

We learned in §6 that the transformation

$$T\equiv\begin{aligned}\rho x_1&=x+y+z,\\ \rho y_1&=z+\alpha y+\alpha^2 z,\\ \rho z_1&=x+\alpha^2 y+\alpha z,\end{aligned}$$

transforms the cubic $x^3+y^3+z^3=0$ into $x^3+y^3+z^3+6xyz=0$. If we make the substitution T in cubic (2) we find that it is transformed into (1); thus T interchanges the two equianharmonic cubics (1) and (2). It may also be verified that T interchanges the equianharmonic cubics (3) and (4). If, however, we make the substitution T in the pair of harmonic cubics

$$x^3+y^3+z^3+6mxyz=0, \qquad \left(m=\frac{-1\pm\sqrt{3}}{2}\right) \tag{25}$$

we find that both of these cubics remain invariant. Thus T is a transformation belonging to the group $G_{36}(j)$, since it leaves invariant a pair of harmonic cubics.

Since T interchanges the equianharmonic cubics (1) and (2), T^2 must leave both of them invariant; hence T^2 is a transformation of the group G_{18}. We readily find $T^2=\left\{\begin{matrix}x\\ z.\\ y\end{matrix}\right.$ We found in §4 that

the transformation $\begin{cases} x \\ z \\ y \end{cases}$ is a perspective transformation of order 2; hence T is of order 4. T^3 is the inverse of T and is given by

$$T^3 \equiv \begin{cases} \rho x_1 = x + y + z, \\ \rho y_1 = x + a^2 y + z, \\ \rho z_1 = x + ay + a^2 z. \end{cases} \qquad (26)$$

The vertex of the perspective transformation T^2 is the point of inflection $A=(0,1,-1)$, and its axis is the harmonic polar of A, viz: $y-z=0$. Hence the other two invariant points B and C of T are on the line $y-z=0$. To find B and C we proceed as follows: Assume the coördinates of B to be $(1,a,a)$; these satisfy $y-z=0$. Substitute these assumed coördinates of B in T and we must get again $(1,a,a)$. Substituting we have

$$\begin{aligned} \rho x_1 &= 1 + 2a \\ \rho y_1 &= 1 + aa + aa^2; \\ \rho z_1 &= 1 + aa^2 + aa \end{aligned} \qquad (27)$$

whence $\frac{1+2a}{1+aa+aa^2}=a$; solving for a we find $a=\frac{-1\pm\sqrt{3}}{2}$. Since we have found two values of a, it follows that we have the coördinates of both B and C. The invariant triangle of T is therefore given by $\begin{cases} 0, & 1, & -1 \\ 1, & \frac{-1+\sqrt{3}}{2}, & \frac{-1+\sqrt{3}}{2} \\ 1, & \frac{-1-\sqrt{3}}{2}, & \frac{1-\sqrt{3}}{2} \end{cases}$. We may check the correctness of this result by using these values in formulas (10) along with $k=i$ and $k'=-i$. We deduce thereby the transformation T.

The invariant points B and C are somehow related to the harmonic cubics of equation (25). We readily find that the point B is on the cubic

$$a \equiv x^3 + y^3 + z^3 + 6\left(\frac{-1-\sqrt{3}}{2}\right)xyz =,$$

and C is on the cubic

$$b \equiv x^3 + y^3 + z^3 + 6\left(\frac{-1+\sqrt{3}}{2}\right)xyz = 0.$$

The six points in which the line $y-z=0$ cuts the two cubics a and

b are in involution, and the invariant points B and C, one on each cubic, constitute the double points of the involution. The other two points on each cubic form pairs of points in the involution. The transformation T^3 evidently has the same invariant triangle as T.

We have now seen how the two transformations T and T^3 of order 4 are related to the point of inflection A and the pair of harmonic cubics a and b. It may be shown in the same way that there are two transformations of order 4 related in the same manner to each of the nine points of inflection and the cubics a and b. The invariant triangle having one vertex at any given point of inflection may easily be found and the corresponding transformations written down by means of formulas (10). In this way we see that there are eighteen transformations of order 4, each of which leaves invariant the pair of harmonic cubics a and b. These eighteen transformations, together with G_{18}, constitute the group G_{36} which we set out to investigate.

§8. The Groups G_{36} (2) and G_{36} (3)

The three groups $G_{36}(j)$ $(j=1,2,3)$ are eqivalent sub-groups of G_{216} and hence are similar in structure. Knowing the structure of G_{36} (1) we infer at once the structure of the other two groups. Take the group whose invariants are the pair of harmonic cubics

$$c\equiv x^3+y^3+z^3+6\alpha\left(\frac{-1+\sqrt{3}}{2}\right)xyz=0,$$

and

$$d\equiv x^3+y^3+z^3+6\alpha\left(\frac{-1-\sqrt{3}}{2}\right)xyz=0.$$

The eighteen transformations of order 4 are distributed so that two of them correspond to each point of inflection. The invariant triangle of such a pair of transformations consists of a point of inflection A and the pair of double points in the involution which the harmonic polar of A cuts from the two cubics c and d.

We shall here follow out one example. Take the point of inflection $A=(0,1,-1)$; its harmonic polar is $y-z=0$. The double points of the involution cut from the cubics c and d by $y-z=0$ are

found to be $B=1,\ \alpha\left(\frac{-1+\sqrt{3}}{2}\right),\ \alpha\left(\frac{-1+\sqrt{3}}{2}\right)$ and

$$=1,\ \alpha\left(\frac{-1-\sqrt{3}}{2}\right),\ \alpha\left(\frac{-1-\sqrt{3}}{2}\right).$$

B is on the curve d and C on c. By means of formulas (10) we find the corresponding inverse pair of transformations to be

$$\begin{cases} \rho x_1 = a^2x+y+z \\ \rho y_1 = ax+y+az \\ \rho z_1 = ax+ay+z \end{cases} \quad \text{and} \quad \begin{cases} a^2x+y+z \\ ax+ay+z \\ ax+y+az. \end{cases} \tag{28}$$

All other transformations of order 4 in this group may be obtained in the same way.

The group G_{36} (2) may also be obtained from G_{36} (1) by transforming the latter by some transformation that changes the harmonic cubics a and b into c and d. $S \equiv \begin{cases} ax \\ y \\ z \end{cases}$ is such a transformation. By substituting the coördinates of the vertices of the invariant triangles of G_{36} (1) in S we obtain those of G_{36} (2). The operation STS^{-1} applied to the transformations of G_{36} (1) give those of G_{36} (2).

The group G_{36} (3) may be obtained in the same way from G_{36} (1) by using the transformation $\begin{cases} a^2x \\ y \\ z \end{cases}$ with the transformations of G_{36} (1); a detailed discussion is not necessary.

Theorem 3.—Every transformation of the group G_{36}(j) (j=1,2,3) leaves invariant a pair of harmonic cubics j; G_{36}(j) contains the eighteen transformations of G_{18} and also eighteen others of type I and order 4. Each of the nine triangles formed by the point of inflection k and the double points of the involution which the harmonic polar of k cuts from the pair of harmonic cubics j is the invariant triangle of a pair of inverse transformations of type I and order 4.

§9. The Group G_{72}.

The three groups G_{36}(j) (j=1,2,3) contains in all fifty-four transformations of order 4. These, together with the eighteen of the group G_{18}, constitute the group G_{72}. This group G_{72} contains therefore no new transformations; accordingly we shall not consider this group at length. These fifty-four transformations of order 4, added to the 162 determined above and found in the four groups G_{54}(i) (i=1,2,3,4), give the 216 transformations of G_{216}.

§10. Conclusion.

The transformations contained in the group G_{216} may be divided into three classes as follows: (1) the eighteen transformations belonging to the Group G_{18}; (2) the 144 transformation in the four groups $G_{54}(i)$ and not belonging to G_{18}; (3) the fifty-four transformations in G_{72} not belonging to G_{18}.

The cubics of the pencil $C+6kH=o$ are distributed into sets of twelve each, such that each set of twelve cubics is an invariant of the group G_{216}. Each set of twelve is divided into four sub-sets of three cubics each; thus: m_i, αm_i, $\alpha^2 m_i$, $(i=1,2,3,4)$ where the m's are the roots of equation (3).

The effect of a transformation of the first class is to transform every cubic of the pencil $C+6kH=o$ into itself. The effect of a transformation of the second class is to cyclically interchange the three cubics of one sub-set in each set of twelve and to cyclically interchange the other three sub-sets. As a special case of this one of the equianharmonic cubics is invariant and the other three are cyclically interchanged; also one of the inflectional triangles is invariant and the other three is cyclically interchanged. The three pairs of harmonic cubics are cyclically interchanged by a transformation of this class. A transformation of the third class interchanges by twos the four equianharmonic cubics and also interchanges by twos the four inflectional triangles. It leaves invariant one pair of harmonic cubics and interchanges the other two pairs.

Since the Hessian of a cubic is a covariant of the cubic, every transformation that leaves a cubic invariant must leave its Hessian also invariant. Thus every transformation of the first class leaves both cubic and Hessian invariant. The Hessian of an equianharmonic cubic is its corresponding inflectional triangle. These are invariant together under a transformation of the second class. The Hessian of a harmonic cubic is the other harmonic cubic of the same pair; these are invariant together under a transformation of the third class.



PLATE I.

Fig. 1. *Taenopteris newberriana*(?). Natural size. No. 5000. Univ. of Kans.

Fig. 1a. Scars, fungi(?). On the rachis of *T. newberriana*(?). Times 3. No. 5000.

Fig. 2. Venation of *T. newberriana*(?). Times 2. No. 5001.

Fig. 3. Sporangia, like bodies between the veins of same. Times 2. No. 5003.

Fig. 4. One of the bodies showing slit on the side. Enlarged. Times 30.

Fig. 5. Another with slit across the top. Times 30.

Fig. 6. Bodies between the veins of *T. coriacea*. Times 2. Taken from specimen Fig. 3, Plate IV.

Fig. 7. *T. newberriana*(??) Natural size. No..5006.

Fig. 8. Venation of *T. coriacea* near the base of the frond. Times 2.

Fig. 9. Venation of the same species near the apex. Times 2.

Fig. 10. Sporangium(?) of *T. coriacea*. Times 30. From Fig. 3, Plate IV.

Fig. 11. Same, showing slit across the top. Times 30.

Fig. 12. Cavity from which the sporangium(?) has been removed. Times 30.

Fig. 13. Venation of T. *newberriana*(?) near the apex. Times 2. From Fig. 1, Plate I.

Fig. 14. *T.* sp. Natural size. No. 5008.

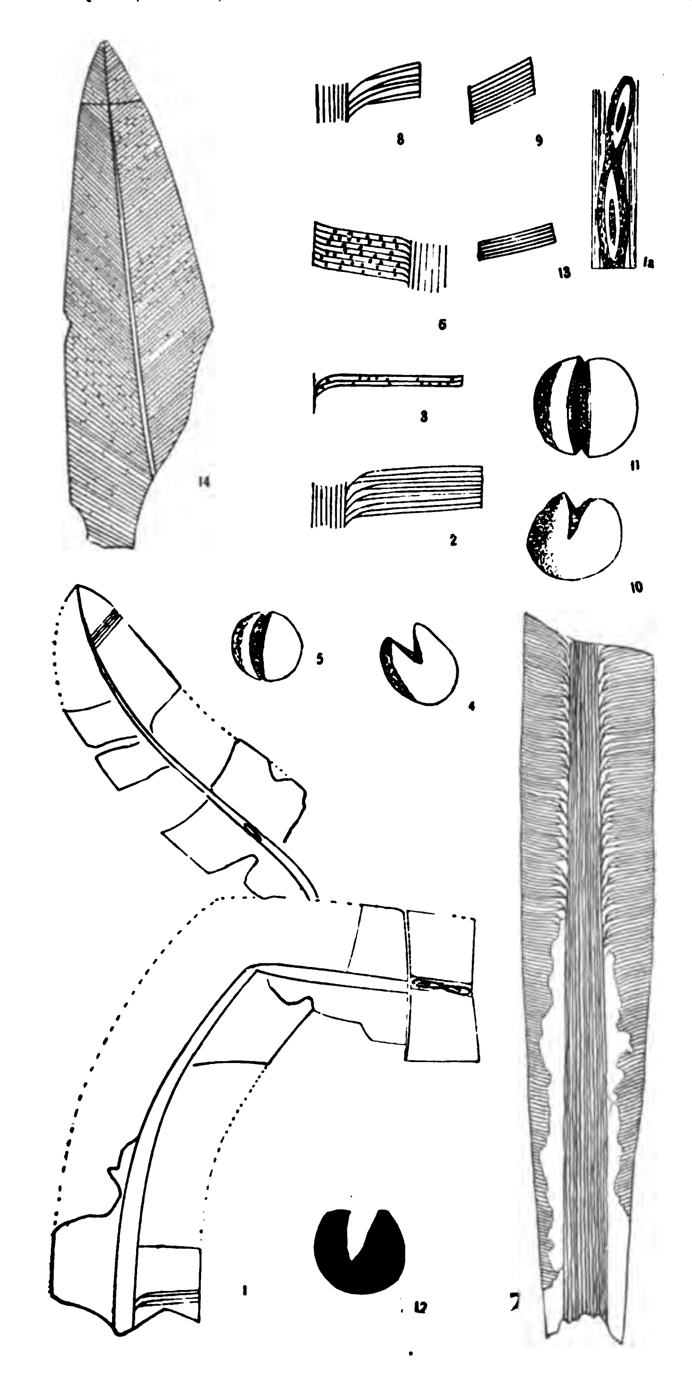

8
9
1a
6
13
3
11
2
10
14
5
4
1
12
7





PLATE II.

Fig. 1. *Taeniopteris coriacea.* Natural size. No. 5022.

Fig. 2. Same species, showing fungi like scars on the lamina. Natural size. No. 5023.


1
2



PLATE III.

Fig. 1. *T. coriacea* with scars, fungi(?) on the rachis. No. 5002.

Fig. 2. Same species, apex of the front. No. 5024.

Fig. 3. *T, coriacea* var. *linearis* var. n.. No. 5004.

Fig. 4. Same. No. 5005.

All natural size.



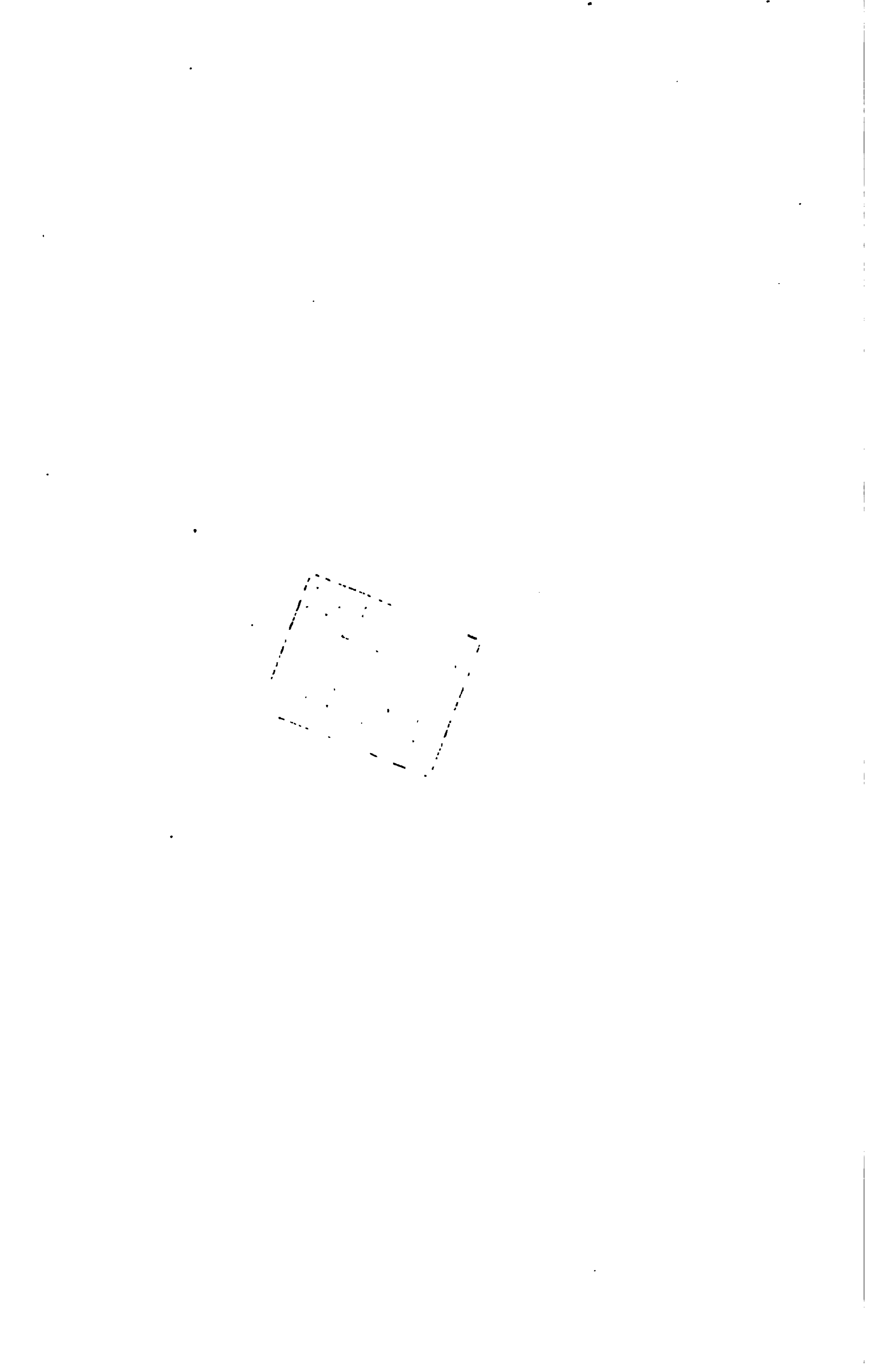




PLATE IV.

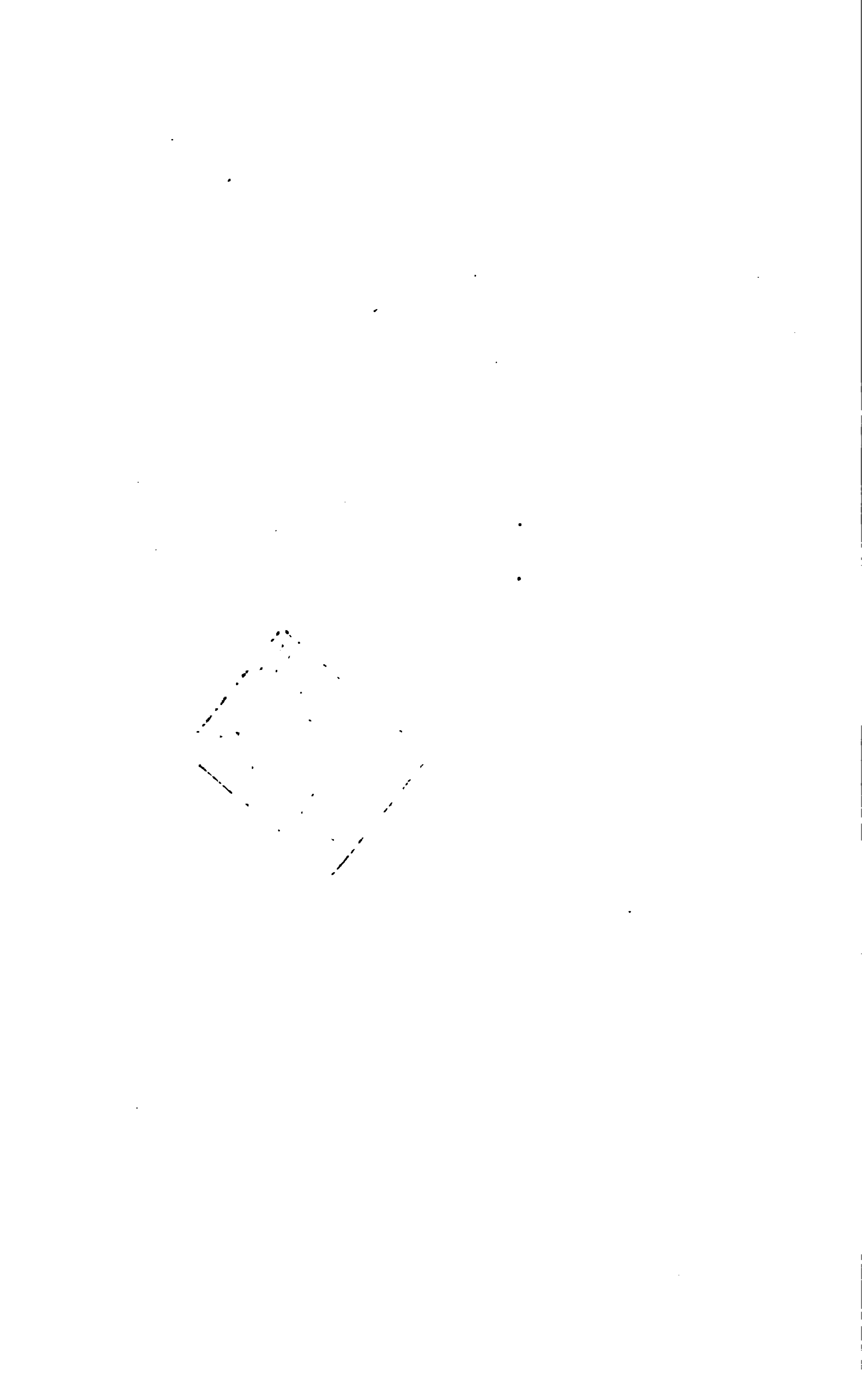
Fig. 1. *Taenioptaris coriacea.* A small frond, slightly reduced. No. 5025.

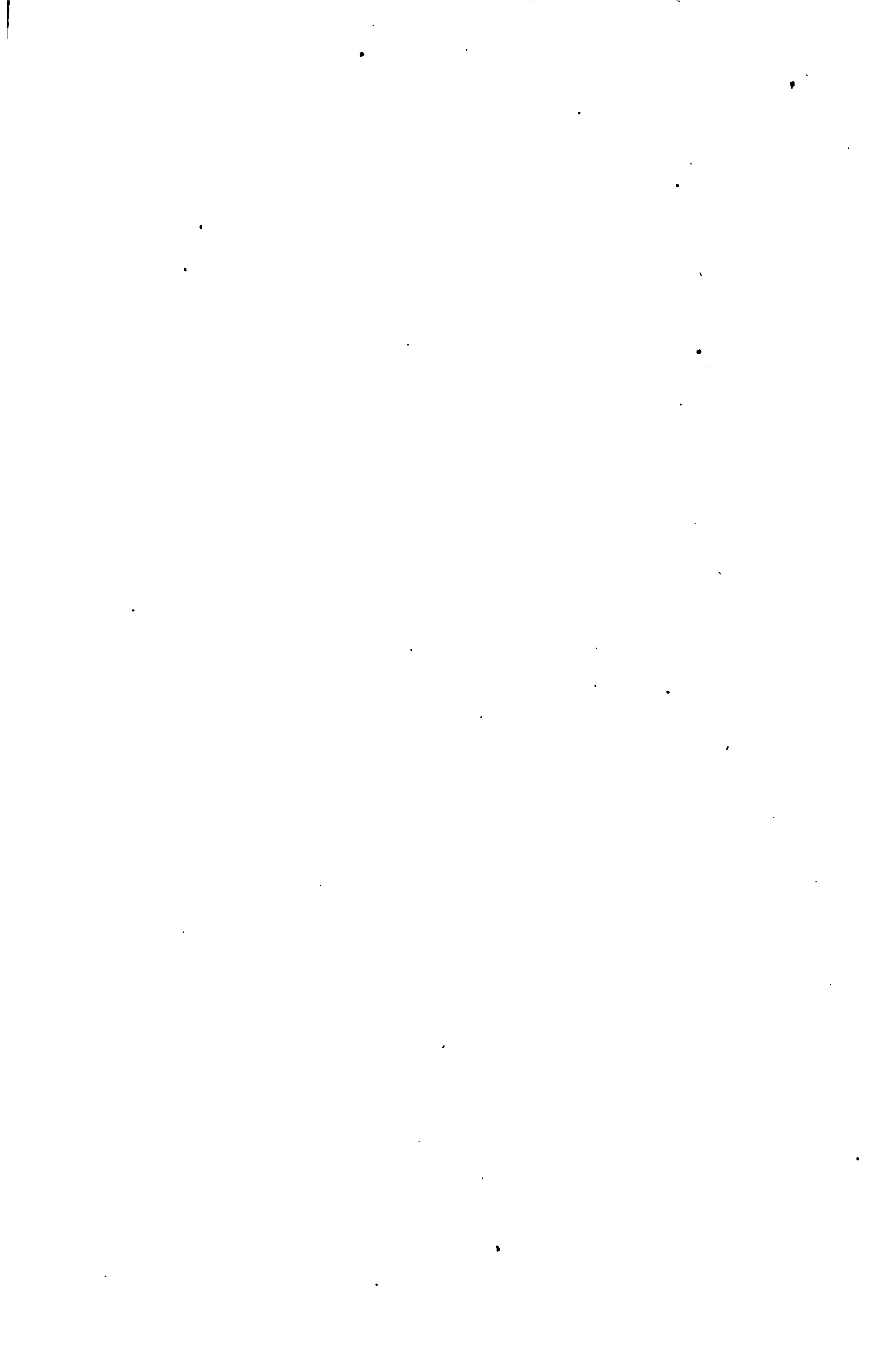
Fig. 2. *T. newberriana(?).* Fragment showing two scars on the rachis and a smaller one in the edge on the lamina. No. 5009.

Fig. 3. Fragment of a small frond of *T. coriacea,* with oval bodies between the veins and casts of the same. No. 5026.

Fig. 4. *T. newberriana(?)* near the base of the frond. No. 5010. Figures 2, 3, and 4, natural size.







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ON THE GROUP AND SUBGROUPS OF REAL COLLINEATIONS LEAVING A TETRAHEDRON INVARIANT.

BY H. B. NEWSON.

THE real collineations in space which have the same invariant tretrahedron are mostly of type I;* the exceptions will be noted later. There are three cases to be considered: (1) The tetrahedron is real in all of its parts; (2) the tretrahedron has two real and two conjugate imaginary vertices, two real and two conjugate imaginary faces, two real and two pairs of conjugate imaginary edges; (3) all the vertices and faces are imaginary in conjugate pairs, while two of the edges are real. These three cases must be treated separately.

§1. THE GROUP WITH REAL INVARIANT TETRAHEDRON AND ITS ONE-PARAMETER SUBGROUPS.

The Group hG_3 (ABCD).—Let T be a collineation of type I, leaving invariant a real tetrahedron (ABCD). T is fully determined by the positions of the four points A, B, C, D, and three constant cross-ratios k, k′, k″. Starting from the vertex A we take for k, k′, k″ the cross-ratios along the lines AB, AC, and AD, respectively. The quantities k, k′ and k″ are independent of one another, and vary independently, thus giving us ∞^3 different collineations, all leaving the four points A, B, C, D, separately invariant. These collineations or projective transformations form a three-parameter group hG_3 (ABCD), the parameters being k, k′, k″.

THEOREM 1. The aggregate of all collineations of type I having the same invariant tetrahedron forms a three-parameter group hG_3 (ABCD).

One-parameter subgroups of hG_3 (ABCD).—We now proceed to show that the group hG_3 (ABCD) contains ∞^2 one-parameter subgroups. Let us assume among the three parameters, k, k,′ k,″ two

* For the types of collineations in space, see Kan. Univ. Quart., Series A, vol. IX, pp. 58-67.

relations, viz., $k'=k^{1-r}$ and $k''=k^{1-r+rs}$, and consider only those transformations which satisfy these assumed relations. These two relations are arrived at in the following manner: The cross-ratio along AB is taken to be k, and that along BC to be k^{-r}; hence that along CA is k^{r-1}, or in the direction AC, it is k^{1-r}. The cross-ratio along BC is now k^{-r}; let that along CD be $(k^{-r})^{-s}$ or k^{rs}; then that along DB must be k^{r-rs}, in order that the product of the three cross-ratios taken in the same order round the triangle should be unity. Since the cross-ratio along AB is k, and that along BD is k^{rs-r}, that along DA must equal k^{r-rs+1}; hence that along AD is k^{1-r+rs}, whence $k''=k^{1-r+rs}$. The three cross-ratios around the triangle ACD are, respectively, k^{1-r}, k^{rs}, and k^{r-rs-1}; their product is evidently unity. We now have the following useful table of these cross ratios:

Along AB : k.
" BC : k^{-r}.
" CD : k^{rs}.
" DB : k^{r-rs}.
" AC : k^{1-r}.
" AD : k^{1-r+rs}.

Suppose that k be allowed to vary while r and s remain constant; these restrictions select from the three-parameter group hG_3 (ABCD) a system of ∞^1 transformations which forms a one-parameter subgroup. To show this, take from the group hG_3 (ABCD) two transformations T and T_1, which have the same values of r and s but different values of k. The one-dimensional transformations along the edges of the invariant tetrahedron in the above order and directions are as follows:

$$T : k, k^{-r}, k^{rs}, k^{r-rs}, k^{1-r}, k^{1-r+rs};$$
$$T_1 : k_1, k_1^{-r}, k_1^{rs}, k_1^{r-rs}, k_1^{1-r}, k_1^{1-r+rs}.$$

Their resultant T_2 is given by

$$T_2 : k_2, k_2^{-r}, k_2^{rs}, k_2^{r-rs}, k_2^{1-r}, k_2^{1-r+rs},$$

where $k_2=kk_1$. Thus the resultant T_2 is a transformation having the same values for r and s as T and T_1; thus the group property is established, and the parameter of the group is k. The law of combination of the parameter k in the one-parameter group is expressed by $k_2=kk_1$.

There is a one-parameter group in hG_3 (ABCD) for each real value of r and s, and thus we see that the three-parameter group hG_3 (ABCD) contains ∞^2 one-parameter subgroups. The properties of one of these one-parameter subgroups are readily inferred from the analogous cases of hyperbolic one-parameter groups in one and two dimensions.

THEOREM 2. The three-parameter group hG_3 (ABCD) contains

∞^2 one-parameter subgroups. For each of these groups r and s have fixed values while k is the variable parameter.

Invariant curves and surfaces of $hG_1\ (ABCD)_{rs}$.—The one-parameter group $hG_1\ (ABCD)_{rs}$ leaves invariant, besides the tetrahedron (ABCD), a system of path curves which are usually curves of double curvature and certain systems of surfaces on which are situated the invariant curves. In order to show this more clearly let us consider the effect on a single point P anywhere in space of all the transformations of the group G_1. Each transformation of the group transforms the point P to some other point P_m. Since the ∞^1 transformations in the group form a continuous system, there are ∞^1 of these points P_m which form a continuous curve, viz., the path curve of the point P.

If we consider in this way the effect of the transformations of the group on all the points of any arbitrary plane, we see that each point of the plane traces a curve. Thus there are ∞^2 of these path curves invariant under all the transformations of G_1. Since our group contains all the pseudo-transformations, corresponding to the values $k=0$ and $k=\infty$, it follows that our path curves all pass through two vertices of the invariant tetrahedron, but not through the other two.

If a surface S be made to pass through ∞^1 of these path curves in such a way that every point on each of these ∞^1 path curves lies on S and also so that every point on S belongs to one of these path curves, then such a surface is an invariant surface of the group G_1. We can best determine these invariant surfaces by resorting to analytic methods.

Equations of invariant surfaces of $hG_1\ (ABCD)_{rs}$.—Let the invariant tetrahedron (ABCD) be the tetrahedron of reference and let T be a transformation of the group G_1 which transforms a point P whose coordinates are (x, y, z, w) to P_1 whose coordinates are x_1, y_1, z_1, w_1. Pass planes through CDP and CDP_1; let these cut AB in Q and Q_1. Then we have the cross-ratio $(ABQQ_1)=k$; hence $\frac{AQ}{BQ}:\frac{AQ_1}{BQ_1}=k$. Using proportional quantities, we have

$$\frac{x_1}{w_1}:\frac{x}{w}=k. \tag{1}$$

In like manner we have the equations

$$\frac{y_1}{x_1}:\frac{y}{x}=k^{-r}, \tag{2}$$

$$\frac{z_1}{y_1}:\frac{z}{y}=k^{rs}, \tag{3}$$

$$\frac{x_1}{z_1}:\frac{x}{z}=k^{r-rs}, \tag{4}$$

$$\frac{w_1}{y_1}:\frac{w}{y}=k^{r-1}, \tag{5}$$

$$\frac{w_1}{z_1}:\frac{w}{z}=k^{r-rs-1}. \tag{6}$$

Suppose that P_1 is a fixed point and P a movable point depending upon the parameter k. Eliminating k from equations (1) and (3), we get

$$\frac{x^{rs}\,y}{w^{rs}\,z}=\frac{x_1^{rs}\,y_1}{w_1^{rs}\,z_1}=\text{Const.}$$

Clearing of fractions, we have

$$x^{rs}\,y=Cw^{rs}\,z. \qquad (I)$$

For different values of C this equation represents a system of invariant surfaces through the path curves of the group.

In like manner eliminating k from equations (2) and (6) we get

$$y^{r-rs-1}\,w^r=Cx^{r-rs-1}\,z^r. \qquad (II)$$

Also from (4) and (5) we get

$$x^{r-1}\,y^{r-rs}=Cz^{r-1}w^{r-rs}. \qquad (III)$$

It should be noted in each of these cases we have eliminated k from the values of the cross-ratios along opposite edges of the tetrahedron. If we eliminate k from the cross-ratios along edges which lie in a plane face of the tetrahedron, we obtain the equation of the plane path curves which lie in that face. The systems of cones whose vertices are the vertices of the invariant tetrahedron and whose bases are the plane path curves of the opposite faces are also invariant surfaces of the group G_1. Eliminating k from (2) and (3), we have

$$y^{s-1}\,z=Cx^s, \qquad (IV)$$

which is the equation of the system of invariant cones whose vertices are at A.

In like manner eliminating k from equations (3) and (6), (1) and (4), (1) and (2), we get

$$z^{r-1}\,y^{1-r+rs}=Cw^{rs}, \qquad (V)$$

$$x^{r-rs-1}\,z=Cw^{r-rs}, \qquad (VI)$$

$$x^{r-1}\,y=Cw^r, \qquad (VII)$$

which are the equations of the invariant cones whose vertices are respectively B, C, and D.

We have thus found seven systems of invariant surfaces of the group G_1; three of these systems are ruled surfaces which pass through four edges of the invariant tetrahedron, and four of them are cones which have their vertices at the vertices of the invariant tetrahedron. The intersections of any two of these systems of surfaces give us the path curves of the group G_1.

THEOREM 3. There are seven distinct families of ruled surfaces invariant under all the transformations of the group $hG_1\,(ABCD)_{rs}$; four of these families are families of cones. The ∞^2 curves of inter-

section of these invariant surfaces are the invariant path curves of the group G_1.

The geometric meaning of r and s.—It is not difficult to determine the geometric meaning of the two constants r and s. Any tangent to a path curve in the plane ABC cuts the side of the triangle ABC in three points which form with the point of contact a range of four points whose cross-ratio is constant and equal to r. Any tangent to a path curve in space cuts the three planes DAB, DAC, DBC in three points which form with the point of contact a range of constant cross-ratio r. For if path curves and tangent be projected from D on the plane ABC we get the path curves and tangent in the plane ABC with the usual meaning of r.

In like manner s is seen to be the cross-ratio of the point of contact of a tangent to a path curve and the three points where the tangent cuts the three planes ABC, ABD, ACD. In general, a tangent to any path curve in space cuts the faces of the invariant tetrahedron (ABCD) in four points; these with the point of contact of the tangent form a set of five points on a line; r and s are two independent cross-ratios of these five points. All other cross-ratios among these five points may be expressed in terms of r and s. Since these five points are all real, r and s must both be real.

THEOREM 4. The constants r and s are two independent cross-ratios among the range of five points in which a tangent to a path curve cuts the tetrahedron (ABCD) and its point of contact.

§2. TWO-PARAMETER SUBGROUPS OF hG_3 (ABCD).

Having shown that the group hG_3 (ABCD) contains ∞^2 one-parameter subgroups, it will be shown next that these one-parameter subgroups unite in certain instances to form two-parameter subgroups of hG_3 (ABCD). It will be found that a two-parameter subgroup of this kind is characterized by the fact that it leaves invariant one and only one family of surfaces on which lie the path curves of its one-parameter subgroups.

Two-parameter groups leaving invariant a family of cones.—If r remains constant while s assumes in turn all real values, we have a system of ∞^1 one-parameter groups, all of which leave invariant the system of cones given by equation (VII); for the equation of this family of cones is independent of s. The other six systems of surfaces given by equations (I)–(VI) vary as s varies, and are not invariant under all the ∞^2 transformations which leave the cones of (VII) unchanged. This system of ∞^2 transformations leaving a family of cones invariant evidently forms a two-parameter group, the parameters being k and s. There is one such group for every value of r.

In like manner, if s is constant and r a variable, we get a two-parameter group, leaving invariant the family of cones given by equation (IV). Again, if r and s vary in such a manner that r–rs remains a constant, we get a two-parameter group which leaves invariant the family of cones given by equation (VI). Also, if r and s vary so that $\frac{rs}{1-r}$ is constant, we get another two-parameter group whose invariant family of cones is given by equation (V). We see in this way that the group hG^{s} (ABCD) contains four singly infinite systems of two-parameter groups, each of which is characterized by an invariant family of cones.

Two-parameter groups leaving invariant a family of ruled surfaces.—If we let r and s vary simultaneously so that their product, rs, remains a constant, we get thereby a system of ∞^1 one-parameter subgroups of hG_3 (ABCD), all of which leave invariant the family of surfaces given by equation (I). The ∞^2 transformations contained in this system of one-parameter groups, since they have a common invariant, viz., equation (I), form a two-parameter group. There is a two-parameter group for each value of the constant rs.

In like manner we see that if 1–s–1/r is a constant, there results a two-parameter group leaving invariant the family of surfaces given by equation (II). Also if $\frac{r-rs}{r-1}$ remains constant, the resulting system of ∞^2 transformations forms a two-parameter group whose invariant family of surfaces is given by equation (III). Thus we see that the group hG_3 (ABCD) contains three singly infinite systems of two-parameter groups, each of which is characterized by an invariant family of ruled surfaces.

THEOREM 5. The group hG_3 (ABCD) contains four singly infinite systems of two-parameter subgroups, each of which leaves invariant a family of cones; and three singly infinite systems of two-parameter subgroups, each of which leaves invariant a family of ruled surfaces.

§ 3. SOME PROPERTIES OF THE ONE-PARAMETER SUBGROUPS OF hG_3 (ABCD).

Transformations in hG_3 (ABCD) with negative values of k, k′, k″.—The group hG_3 (ABCD) contains ∞^3 transformations depending upon three variable parameters k, k′, k″, which assume in turn all real values, both positive and negative. Our next problem is to determine whether all the transformations in hG_3 (ABCD) are to be found in these ∞^2 one-parameter subgroups, and what transformations, if any, are common to two or more of these subgroups.

In order to solve these problems we resort to a simple geometrical device where k, k′ and k″ are taken to be the rectangular coordinates of

a point in space. It is evident, since these parameters are independent, that there is a point in space corresponding to every transformation of the group hG_3 (ABCD). All transformations whose parameters satisfy the relations

$$k'=k^{1-r} \text{ and } k''=k^{1-r+rs}$$

form a one-parameter subgroup of hG_3 (ABCD). Hence the curve of intersection of the two cylinders whose equations are $y=x^{1-r}$ and $z=x^{1-r+rs}$ represents a one-parameter group hG_1 $(ABCD)_{rs}$ and the individual points on the curve represent the individual transformations of the group. If we give to r and s all real values we have a system of ∞^2 curves which represents the system of ∞^2 one-parameter subgroups of hG_3 (ABCD).

An examination of the equations $y=x^{1-r}$ and $z=x^{1-r+rs}$ shows that one branch of the curve lies in the first octant for all values of r and s; and if r is an irrational number, the curve lies wholly in the first octant. If r and s are both rational, r with odd numerator and odd denominator, s with even numerator and odd denominator, the curve lies in the first and second octants. If r and s are both rational, r with even numerator and odd denominator, s with odd numerator and even denominator, the curve lies in the first and third octants. If r is rational with odd numerator and even denominator while s is irrational or rational with odd numerator and odd denominator, the curve lies in the first and fourth octants. If r is rational with odd numerator and s rational with odd numerator and even denominator, the curve lies in the first and fifth octants. If r and s are both rational, each with odd numerator and odd denominator, the curve lies in the first and sixth octants. If r and s are both rational, r with even numerator and odd denominator, s with odd denominator, the curve lies in the first and seventh octants. If r and s are both rational, r with odd numerator and even denominator, s with even numerator and odd denominator, the curve lies in the first and eighth octants.

The curves of the family, $y=x^{1-r}$ and $z=x^{1-r+rs}$, contain every point in the first octant, but not every point in the other seven octants. Consequently the group hG_3 (ABCD) contains transformations which are not included in any of its one-parameter subgroups. Such a transformation has one or more of its cross-ratio parameters negative and such that their values do not satisfy algebraic equations of the form $k'^n=k''^m$, $k''^n=k^l$, where l, m and n are integers.

Transformations common to two or more one-parameter subgroups of hG_3 (ABCD).—In order to find all points common to any two curves of the family representing the system of one-parameter subgroups of hG_3 (ABCD), we solve the simultaneous system of equations

$$y=x^{1-r},\ z=x^{1-r+rs};\ y=x^{1-r'},\ z=x^{1-r'+r's'}.$$

We observe that the points (0, 0, 0), (∞, ∞, ∞), and (1, 1, 1) belong to every curve of the family; hence every one-parameter subgroup of hG_3 (ABCD) contains the identical transformation (1, 1, 1) and the two pseudo-transformations (0, 0, 0) and (∞, ∞, ∞).

From the above equations we have $x^{r'-r}=1$, and $x^{r'-r+rs-r's'}=1$ or $x^{rs-r's'}=1$. Since x is real, it can have only the values ± 1; substituting these values of x in $y=x^{1-r}$ and $z=x^{1-r+rs}$, we see that the real values of y and z are limited to the numbers ± 1. Hence, the only points common to two curves of the family in addition to those mentioned above are (1, 1, –1), (1, –1, 1), (–1, 1, 1), (1, –1, –1), (–1, 1, –1), (–1, –1, 1), (–1, –1, –1). The point (–1, 1, 1) is common to every curve of the family which lies partly in the second octant. The corresponding transformation is an involutoric perspective transformation of type VI, having its vertex at B and the plane ADC for its axial plane. The transformations corresponding to the points (1, 1, –1), (1, –1, 1), (–1, –1, –1) are also involutoric perspective transformations of type VI, with vertices at D, C, and A, respectively, and whose axial planes are the opposite faces of the tetrahedron (ABCD).

The transformations corresponding to the points (1, –1, –1), (–1, 1, –1), and (–1, –1, 1) are involutoric skew perspective transformations of type X, whose skew axes are respectively the edges of AD and CD, AC and BD, AD and BC of the invariant tetrahedron (ABCD). Each of these transformations belongs to every one-parameter subgroup of hG_3 (ABCD) whose representative curve lies partly in the eighth, sixth and third octants, respectively.

THEOREM 6. The ∞^2 one-parameter subgroups of hG_3 (ABCD) do not include all the transformations in hG_3 (ABCD); a transformation not belonging to a one-parameter subgroup has one or more of its cross-ratio parameters negative. Every subgroup hG_1 $(ABCD)_{rs}$ for which r and s are rational contains one involutoric perspective transformation either of type VI or X.

§4. SUBGROUPS OF TYPES VI, VIII AND X IN hG_3 (ABCD).

Subgroups of type VIII in hG_3 (ABCD).—The constants r and s may have such values that all the one-dimensional transformations along the same edge are identical transformations. This may occur in six different ways, since there are six edges of the tetrahedron.

If $r=1$ while s remains finite, we have an identical transformation along AC. If $r=0$ while rs remains finite, we have an identical transformation along BC. If $r=\infty$, we see that the transformation along AB is identical. If $s=1$ and r is finite, we have an identical transformation along BD. If $s=0$ while r remains finite, the transformation along CD is identical. If $rs=r-1$, the transformation along AD is identical.

In the case that a transformation of type I degenerates to type VIII, one of the families of invariant surfaces degenerates into a family of planes intersecting in one edge of the tetrahedron; this edge is opposite the edge which is the line of invariant points. All transformations of type VIII in hG_3 (ABCD) leaving the same edge invariant form a two-parameter group. The path curves of the subgroups of these two-parameter groups are always plane curves.

THEOREM 7. The group hG_3 (ABCD) contains six two-parameter subgroups of type VIII; these are given when $r=1, 0, \infty$; and $s=1, 0, \frac{r-1}{r}$.

Subgroups of type VI in hG_3 (ABCD).—For certain values of r and s a transformation of type I reduces to type VI. In such a case all points in one of the invariant planes of type I are invariant points, and all lines through the opposite vertex of (ABCD) are invariant lines.

Let $r=0$ and let s have any finite value; then the transformations along BC, CD and DB are all identical; hence the two-dimensional transformation in the face BCD is identical. At the same time the cross-ratios along AB, AC and AD are all equal to k. Such a transformation is evidently of type VI. Let $r=1$ and $s=0$; then the two-dimensional transformation in the face ACD is identical, and the one-dimensional transformations along BA, BC and BD are all equal. Again, let $r=\infty$ and $s=1$; then the two-dimensional transformation in the face ABD is identical, and the one-dimensional transformations along CA, CB and CD are all equal. Finally, let $r=\infty$ and $s=\infty$; then every point in the face ABC is an invariant point and the one-dimensional transformations along DA, DB and DC are all equal.

It is evident in each of the above cases that the invariant surfaces are all planes or cones and the path curves are all straight lines.

THEOREM 8. The group hG_3 (ABCD) contains four one-parameter subgroups of type VI; these are given by the following sets of values of r and s: $(0, s)$, $(1, 0)$, $(\infty, 1)$, (∞, ∞).

Subgroups of type X in hG_3 (ABCD).—For certain values of r and s a transformation of type I reduces to one of type X. From the nature of type X it is evident that it must occur as a special case of type VIII, when the two one-dimensional transformations along opposite edges of (ABCD) are identical transformations.

Let $r=1$ and $s=1$; then the one-dimensional transformations along AC and BD are both identical transformations, and thus every point on each of these edges is an invariant point. The cross-ratios along AB, AD, CB and CD are all equal. The invariant families of surfaces I–VII reduce for $r=1$ and $s=1$ to the following:

$$xy=Czw,\ xw=Cyz,\ x=Cz, \text{ and } y=Cw.$$

The path curves are evidently straight lines and constitute the congruence of lines joining every point on AC to every point on BD.

Again, let $r=\infty$ and $s=0$ with the condition that $rs=0$; then the transformations along AB and CD are both identical, while those along AC, AD, BC and BD are all equal. The invariant surfaces and path curves are analogous to those above. In like manner, if we make $r=0$ and $s=\infty$, and $rs=-1$, we get identical transformations along BC and AD; the cross-ratios along AB, AC, DB and DC are all equal, the invariant surfaces are pencils of quadrics and pencils of planes, the path curves are all straight lines.

THEOREM 9. The group $hG_8(ABCD)$ contains three one-parameter groups of type X; these are given by the following sets of values of r and s: (1, 1), (∞, 0), (0, ∞, $rs=-1$.)

§5. SOME SPECIAL SUBGROUPS OF $hG_3(ABCD)$.

Subgroups with invariant quadric cones.—For certain values of r and s the invariant cones whose equations are (IV)-(VII) are cones of the second order. One of these families of cones will be of the second order when the plane path curves in one the faces of the tetrahedron are conics.

Equation (IV) represents a family of quadric cones for three values of s, viz., $s=-1, 2, \frac{1}{2}$; equation (V) represents quadric cones when $\frac{rs}{r-1}=-1, 2, \frac{1}{2}$; equation (VI) represents quadric cones when $r-rs=-1, 2, \frac{1}{2}$; equation (VII) represents quadric cones when $r=-1, 2, \frac{1}{2}$. Consider the case when $r=-1$; s may assume ∞^1 different values, and hence there are ∞^2 one-parameter groups which leave invariant the same family of quadric cones. These form a two-parameter group. The vertex of the cones of the family are at D, and the lines DA and DB are elements common to all the cones of the family. Thus we see that there are twelve two-parameter subgroups of hG_3 (ABCD) which leave invariant a family of quadric cones.

THEOREM 10. The group hG_3 (ABCD) contains twelve two-parameter subgroups each of which leaves invariant a family of quadric cones; these are given by the values of r and s as follows: $r=-1, 2, \frac{1}{2}$; $s=-1, 2, \frac{1}{2}$; $r-rs=-1, 2, \frac{1}{2}$; $\frac{rs}{r-1}=-1, 2, \frac{1}{2}$.

Subgroups with invariant quadric surfaces.—We now seek the most general conditions under which the invariant surfaces of a one-parameter subgroup of hG_3 (ABCD) shall be a family of quadric surfaces. One or more of the three families of surfaces whose equations are (I), (II), (III) will reduce to quadrics for certain values of r and s. The surfaces given by (I) are quadrics when $rs=\pm1$; equation (II) gives quadrics when $r-rs-1=\pm r$; equation (III) yields quad-

rics when $r-1=\pm(r-rs)$. The condition $r-rs-1=\pm r$ reduces to $rs=-1$ and $rs=2r-1$; the condition $r-1=\pm(r-rs)$ reduces to $rs=1$ and $rs=2r-1$. Hence we have only three relations beween r and s for which at least one family of invariant surfaces are quadrics.

Putting $rs=1$ in (I), (II), (III), we get, after reduction,

$$\text{(I)},\ xy=Czw;\ \text{(II)},\ y^{r-2}w=Cx^{r-2}z;\ \text{(III)},\ xy=Czw.$$

Thus the first and third families of surfaces reduce to the same family of quadrics.

Putting $rs=-1$ in (I), (II), (III), we have

$$\text{(I)},\ xz=Cyz;\ \text{(II)},\ xz=Cyw;\ \text{(III)},\ x^{r-1}y^{r+1}=Cz^{r-1}w^{r+1}.$$

Here we see that (I) and (II) give the same system of quadrics. Putting $rs=2r-1$ in (I), (II), (III), we get

$$\text{(I)},\ x^{2r-1}y=Czw^{2r-1};\ \text{(II)},\ xw=Cyz;\ \text{(III)},\ xw=Cyz.$$

From these three cases we see that, if one of our families of invariant surfaces are quadrics, another is also, and these two families of quadrics coincide.

The invariant tetrahedron (ABCD) is the common self-polar tetrahedron of these families of quadrics. All quadrics of the system $xy=Czw$ pass through the edges AC, CD, AB, and BD; the edges AD and BC are reciprocal polars of all quadrics of the family. Similar properties hold for the other two families $xz=Cyw$ and $xw=Cyz$.

Each of these systems of quadrics remains invariant under ∞^2 transformations which form a two-parameter subgroup of hG_3 (ABCD).

THEOREM 11. There are three two-parameter subgroups of hG_3 (ABCD) each of which leaves invariant a family of quadric surfaces; these are given by $rs=1$, $rs=-1$, $rs=2r-1$.

Subgroups whose path curves are all conics.—We now proceed to investigate the one-parameter subgroups of hG_3 (ABCD) whose path curves are all conics. Since conics are plane curves, such a one-parameter group must be of type VIII. We find in § 4 that there are six two-parameter subgroups of type VIII in hG_3 (ABCD); hence, a one-parameter subgroup of hG_3 (ABCD) whose path curves are all conics must be a one-parameter subgroup of one of these groups of type VIII.

To obtain one of these two-parameter subgroups of type VIII let $s=1$. The line DB is a line of invariant points, and all planes through the opposite edge AC are invariant planes. The path curves are all alike in these invariant planes, and hence it is sufficient to examine them in one of these planes, as ABC. The path curves in the plane ABC are conics for three different values of r, viz., $r=-1, 2, \frac{1}{2}$.

For $r=-1$, 2, and $\frac{1}{2}$ the conics have double contact at A and C, B and C, and A and B, respectively.

The case where $r=-1$ is essentially different from the other two cases where $r=2$ and $r=\frac{1}{2}$. In the first case the conics in all the planes through AC have double contact at A and C; in the second case the conics in all these planes have only one point in common, C when $r=2$ and A when $r=\frac{1}{2}$. The invariant surfaces in the two cases are very different and worthy of attention. Let $s=1$ and $r=-1$ in equations (I), (II), (III); we thus get

$$\text{(I)},\ xz=Cyw;\ \text{(II)},\ xz=Cyw;\ \text{(III)},\ x=Cz.$$

In this case we have a family of invariant quadrics. Again, let $s=1$ and $r=2$ in the same equations, and we have

$$\text{(I)},\ x^2y=Cw^2z;\ \text{(II)},\ xw^2=Cyz^2;\ \text{(III)},\ x=Cz.$$

Let $s=1$ and $r=\frac{1}{2}$, and we get

$$\text{(I)},\ xy^2=Cwz^2;\ \text{(II)},\ x^2w=Cy^2z;\ \text{(III)},\ x=Cz.$$

In both these latter cases the invariant surfaces are ruled surfaces of the third order.

Instead of taking the edge BD for the line of invariant points any other one of the six edges may be made the line of invariant points; hence there are six such cases as the above to be considered.

THEOREM 12. There are eighteen one-parameter subgroups of hG_3 (ABCD) for which the path curves are conics; six of these groups leave invariant a family of quadrics and twelve of them leave invariant families of cubic surfaces. The first six are given by the following values of r and s: $(-1, 1)$, $(1/2, 0)$, $(2, 1/2)$, $(1, -1)$, $(0, \infty, rs=-1)$, $(\infty, 2)$. The remaining twelve result from the following values of r and s: $(2, 1)$, $(1/2, 1)$, $(2, 0)$, $(-1, 2)$, $(1/2, -1)$, $(1, 2)$, $(1, 1/2)$, $(0, \infty, rs=2)$, $(0, \infty, rs=1/2)$, $(\infty, -1)$, $(\infty, 1/2)$, $(-1, 2)$.

Subgroups whose path curves are twisted cubics.—If we give to r and s such values that two of the families of invariant cones (IV) . . . (VII) are quadric cones so situated that all the cones of both families have one edge of the tetrahedron (ABCD) in common, the path curves of the resulting one-parameter groups will be twisted cubics; for the intersection of two quadric cones having one element in common is a twisted cubic passing through the vertices of the two cones and having the common element for a secant line.

For example, let $r=-1$ and $s=-1$; equations (IV) and (VII) reduce respectively to

$$xz=Cy^2 \text{ and } yw=Cx^2.$$

The first equation represents a family of quadric cones having double contact along AB and AD; the second represents a family of cones

having double contact along DC and DA. Since every cone of each family has the line AD in common, their curves of intersection are a system of ∞^2 twisted cubics passing through A and D. For these values of r and s the invariant systems of surfaces given by (1), (II), (III) become

$$\text{(I)}, xy=Czw; \text{ (II)}, x^3z=Cy^3w; \text{ (III)}, xy=Czw.$$

Thus we see that the cubic path curves also appear as the intersection of a family of quadrics with a family of quartics.

Again, let us put $r=1/2$ and $s=2$; equations (IV) and (VII) reduce respectively to

$$yz=Cx^2 \text{ and } xw=Cy^2.$$

These two families of quadric cones have also the element AD in common. Equations (I), (II), (III) become for these values of r and s

$$\text{(I)}, xy=Czw; \text{ (II)}, x^3w=Cy^3z; \text{ (III)}, xy=Czw.$$

The path curves are again twisted cubics through A and D and lie on the family of quadrics $xy=Czw$; but they now appear as the intersection of this family of quadrics with another family of quartics.

In like manner it can be shown that the path curves are twisted cubics for ten other pairs of values of r and s, as follows: $r=3$, $s=1/3$; $r=3/2$, $s=1/3$; common chord BC: $r=-2$, $s=1/2$; $r=-1/2$, $s=2$; common chord AC: $r=2$, $s=3/2$; $r=-1$, $s=3$; common chord CD: $r=2$, $s=-1/2$; $r=1/2$, $s=-2$; common chord BD: $r=1/3$, $s=-1$; $r=2/3$, $s=1/2$; common chord AB.

THEOREM 13.—There are twelve one-parameter subgroups of hG_3 (ABCD) for which the path curves are twisted cubics; these are given by the following values of r and s: ($r=-1$, $s=-1$), ($r=1/2$, $s=2$), ($r=3$, $s=1/3$), ($r=3/2$, $s=1/3$), ($r=-2$, $s=1/2$), ($r=-1/2$, $s=2$), ($r=2$, $s=3/2$), ($r=-1$, $s=3$), ($r=2$, $s=-1/2$), ($r=1/2$, $s=-2$), ($r=1/3$, $s=-1$), ($r=2/3$, $s=1/2$).

§6. THE GROUPS eG_3 (ABCD) AND eeG_3 (ABCD) AND THEIR SUBGROUPS.

We shall now consider briefly the two cases where the invariant tetrahedron (ABCD) is not real in all of its parts. The first, called the single elliptic case, is where the tetrahedron has two real and two conjugate imaginary vertices; the second, called the double elliptic case, is where the tetrahedron has two pairs of conjugate imaginary vertices. These three-parameter groups are designated by eG_3 (ABCD) and eeG_3 (ABCD), respectively.

The group eG_3 (ABCD) and its subgroups.—Let B and C be a pair of conjugate imaginary vertices of the tetrahedron (ABCD). The cross-ratios k and k′ along the conjugate imaginary lines AB and

AC are conjugate imaginary quantities; also those along DC and DB are conjugate imaginary quantities. The cross-ratio k″ along AD is real, and that along BC is of the form exp. ni θ. As in the hyperbolic case, we may put $k'=k^{1-r}$ and $k''=k^{1-r+rs}$; r and s are usually both complex quantities. It can be shown without difficulty that the condition that the collineation shall be real requires that r shall be of the form $1+\exp. 2i\,\phi$, and s of the form $\frac{\exp. 2i\psi}{\exp. 2i\psi+1}$. In the complex plane the locus of r is the unit circle about the unit point, and the locus of s is the line $x=1/2$.

The cross-ratios along the six edges of the tetrahedron may be written:

$$\begin{aligned}
AB &: \exp.\,(\tan\phi+i)\,\theta,\\
BC &: \exp.\,-2i\,\theta,\\
CD &: \exp.\,(\tan\psi+i)\,\theta,\\
DB &: \exp.\,(-\tan\psi+i)\,\theta,\\
AC &: \exp.\,(\tan\phi+i)\,\theta,\\
AD &: \exp.\,(\tan\phi+\tan\psi)\,\theta.
\end{aligned}$$

In these expressions θ is the variable and assumes in turn all real values from $-\infty$ to $+\infty$. Since k is real, both positive and negative, while the value of exp. $(\tan\phi+\tan\psi)\,\theta$ is only positive, it follows that half of the transformations in eG_3 (ABCD) are not contained in its one- and two-parameter subgroups, viz., those for which k is negative.

The group eG_3 (ABCD) contains two real subgroups of type VI, the vertices being A and D; it also contains two real subgroups of type VIII, one hyberbolic and the other elliptic, whose axes of invariant points are, respectively, BC and AD; it also contains one subgroup of type X, which is common to the two subgroups of type VIII.

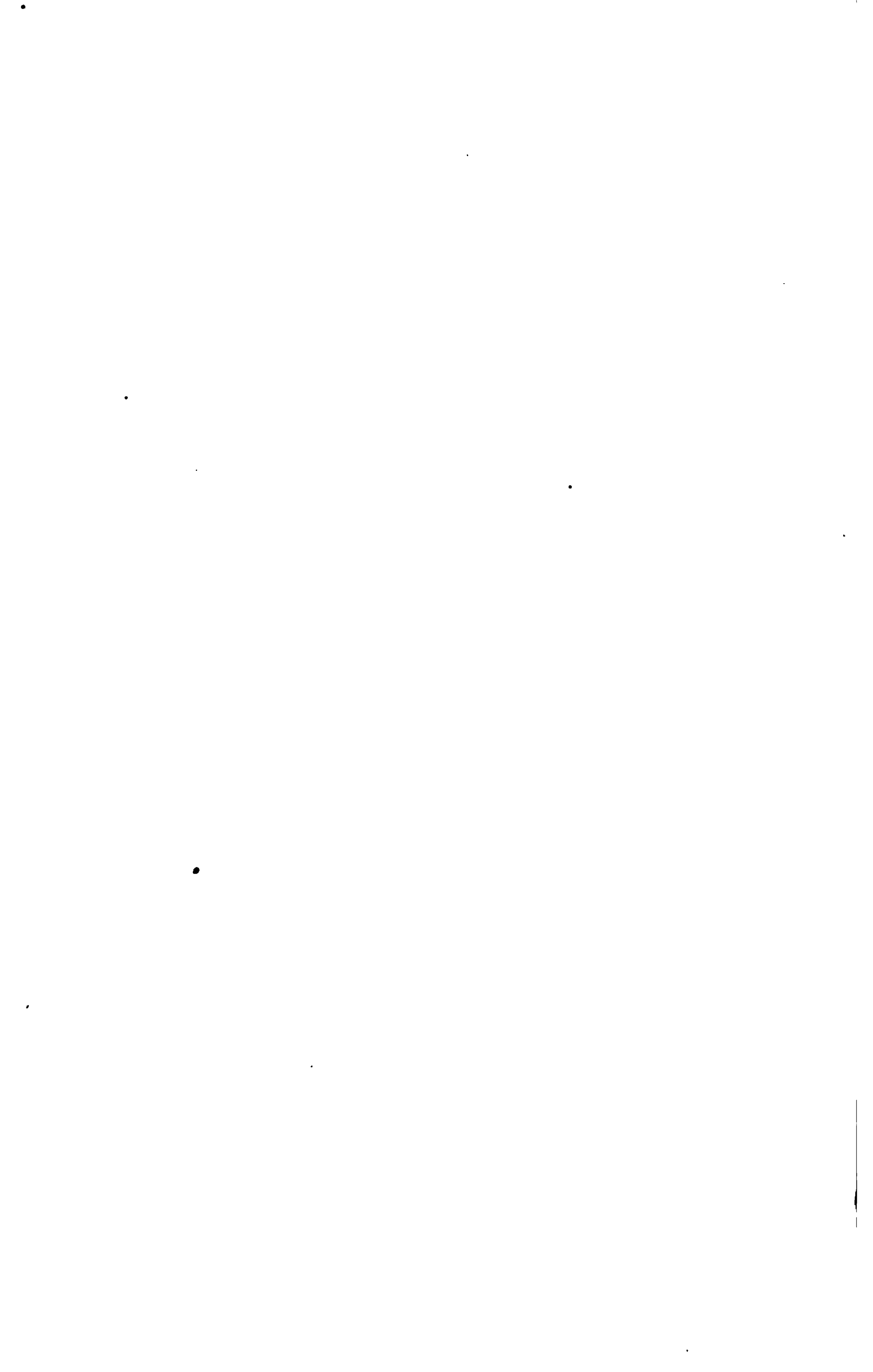
The group eG_3 (ABCD) has only two real two-parameter subgroups leaving invariant a family of quadric cones. These two families of cones do not have an element in common; hence there are no real subgroups leaving invariant a family of cubic path curves. When ϕ and ψ are supplementary, one of the families of invariant surfaces consist of quadrics. These statements may be easily verified by the reader.

The group eeG_3 *(ABCD)*.—Let AD and BC be taken as the two real edges of the invariant tetrahedron (ABCD) in the double elliptic case. Along these real edges the one-dimensional transformations are elliptic, so that the cross-ratios are both of the form exp. ni θ. It follows from these conditions that k must be assumed in the form of

exp. i θ, and that r and s are both real. The cross-ratios along the six edges of the tetrahedron (ABCD) are written thus:

$$\begin{aligned}
AB &: k = \exp.\, i\,\theta, \\
BC &: k^{-r} = \exp.\, ri\,\theta, \\
CD &: k^{rs} = \exp.\, rsi\,\theta, \\
DB &: k^{r-rs} = \exp.\,(r-rs)i\,\theta, \\
AC &: k^{1-r} = \exp.\,(1-r)i\,\theta, \\
AD &: k^{1-s+rs} = \exp.\,(1-r+rs)i\,\theta.
\end{aligned}$$

It is now evident that every transformation in eeG_3 (ABCD) is to be found in some one of its one-parameter subgroups. The group eeG_3 (ABCD) contains two real subgroups of type VIII, both elliptic, and one of type X, which is common to the two of type VIII.



THE DIMORPHISM OF CAMBARUS, I.

BY J. ARTHUR HARRIS.

THE existence of two markedly different forms of males in the genus *Cambarus* has long been known. The fact was first noticed by Louis Agassiz and Henry James Clark,[1] and communicated[2] by the former to Dr. Hermann A. Hagen, who verified the observation for all the species of *Cambarus*, of which he had opportunity of examining a large number of specimens.[3] Doctor Hagen, in his monograph, whenever material was available, described both forms of males, designating them as form I and form II. Since that time, in taxonomic work, a complete description has always covered both forms of the male; a fact of no small importance, since the discrepancies in the descriptions of some of the earlier writers may be due to the fact that the presence of two forms of males in each species had not yet been recognized.

The external differences between the first- and second-form males have been well described by Hagen[4] and Faxon.[5]

The differences may here be just as well stated in Doctor Faxon's words:[6]

"The differences between the two forms affect more especially the first pair of abdominal appendages, organs concerned in the act of coition, but also extend to the general form and sculpture of the body. In one form [unhappily called by Doctor Hagen the 'second-form'] the first pair of abdominal appendages have a structure nearly like that seen in all young males. The hook on the third joint of the third [in some species, of the third and fourth] pair of legs is small, and in the sculpture of the shell and shape of the claws this form approaches the female. In the other form [Hagen's 'first-form'], the articulations near the base of the first pair of abdominal appendages are gone and the whole member is much more highly specialized, the terminal hooks being horny, more widely separated, and in every way more highly developed; in those species with bifid tips to these appendages, the branches are longer, slender, more widely separated, and stiffer; the hooks on the thoracic legs are longer and more perfectly finished, the sculpture of the whole body is more pronounced, and the claws are longer and more powerful. No intermediate conditions are found, and there is no relation between these forms and the size of the individual, the 'second form' being large and the 'first form' small, or *vice versa*."

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1. See Faxon (Walter), "On the so-called Dimorphism in the Genus *Cambarus*," Amer. Jour. Sci., vol. XXVII, pp. 42-44.

2. See Hagen (Hermann A.), "Monograph of the North American Astacidæ," Ill. Cat. Mus. Comp. Zool., Harvard Coll. 1870.

3. Hagen, loc. cit., p. 24.

4. Hagen, loc. cit.

5. Faxon, loc. cit. Also, "A Revision of the Astacidæ," pt. I, Mem. Mus. Comp. Zool., vol. X, No. 4. 1885.

6. Faxon, "On so-called Dimorphism," etc.

Doctor Hagen made an anatomical examination[7] of first- and second form males of *C. acutus* Girard, *C. virilis* Hagen, and *C. bartonii* Fabricius. His observations were made from a very limited number of specimens—probably only two from each species—and no note was made of the time of year the material was taken, a factor the significance of which he seems to have entirely overlooked. His observations were that the testis was decidedly larger in the first- than in the second-form. He says, in fact: "The sexual parts of the second-form males are so much less developed that it would be allowable to consider them as sterile." Hagen's idea was that in the older males of the second-form the sexual organs have failed to develop and are consequently non-functional. He says: "But the great number of full-grown second-form specimens in every species, which are often even larger than the first-form males, seems to prove that they are individuals which have remained in a sexual stage that does not agree with their corporal development—in short, they are, perhaps, sterile."

The size of the arthropod testis, in fact, depends largely upon the condition of the elements, being, for instance, larger when the sperm-cells are in the spermatocyte stages than when the spermatozoa are mature, and being, of course, smaller still after the testis has been evacuated.

So far as I have been able to observe, the testis of first- and second-form males of the same size, taken at the same season of the year, are equally developed, it being impossible to determine from an examination of the testis alone whether a given individual is first- or second-form.

Faxon[8] observed that the so-called first- and second-form males merely represent alternating stages in the life of the individual. Specimens of *C. rusticus* Girard kept in his laboratory copulated freely. Shortly after they exuviated, and, while yet soft, they were thrown with their casts into alcohol. Upon later examination, it was observed that the casts were first-form—the form in which the animal had approached the female—while the animals themselves were second-form.

The same was noticed for a specimen of *C. propinquus* Girard which had been preserved with its cast.

I have had the opportunity of watching quite closely a small stagnant pond near Lawrence, Kan., in which occur *C. gracilis* Bundy, *C. virilis* Hagen, and *C. immunis* Hagen. As *C. immunis* was by far the most abundant, observations were made on it. In the late summer and autumn, the proportion of first-form males gradually increased; there seems to be, so far as my observations go, no definite

7. Hagen, loc. cit., pp. 22-24.
8. Faxon, "On so-called Dimorphism," etc.

time at which exuviation takes place. This point, however, should be determined more definitely. In the spring of 1901, *C. immunis* appeared in the above-mentioned pond early in March. All males collected up to April 15 were first-form. On April 20, the pond was again examined and a large number of second-form males, yet soft from exuviation, were found. On April 25, the most of the males taken were second-form, and none of them had yet attained the normal degree of hardness. A large proportion of the first-form males were evidently nearly ready to exuviate. None, however, were observed in the act. Upon slipping the old "shell" from first-form males ready to exuviate, the animals in their new condition were plainly seen to be second-form. Thus, my somewhat more extended observations for *C. immunis* Hagen confirm Doctor Faxon's important discovery, that the "first" and "second" forms are simply alternating periods in the life of the individual.

While neither so extended nor careful as for *C. immunis*, my observations on the habits of *C. virilis* led me to believe that the process is the same in this species.

Two individuals taken in the above-mentioned pond are deserving of special consideration. The first (No. 34), a specimen of nearly three inches in length, was collected on the morning of April 29, 1901, and thrown with many others into a collecting can. In the afternoon, when the material was removed and examined, it was noticed that this specimen had died during the process of exuviation. The cast was plainly second-form, as was also the animal in its new condition. The pleopods and the hooks on the ischiopodites were decidedly and plainly second-form in both the cast and the exuviated animal. The old chelæ resembled those of the second-form, but those of the soft animal were so much distorted that they offered no evidence of value.

The other specimen (No. 35) was collected while very soft from exuviation. It was in every respect a clearly marked first-form male, and, while the cast was not secured, it seems altogether probable that this animal must have passed the winter in the first-form condition. All males taken up to this time in the spring, with the one exception of No. 34, were first-form males, as were all males of this species taken late in the fall.

C. immunis ceases to be constantly second-form long before it attains the size of No. 34. No. 35, while a large specimen for *C. immunis*, was very slightly, if any, larger than other specimens collected in the same place, which changed from first- to second-form upon exuviation. This would seem to indicate that, if there is finally reached a period in the life of the animal in which it is constantly in the first-

form condition and if No. 35 had reached this stage, the beginning of this period varies with different individuals.

Thus, in the two cases mentioned above, it would seem that we have exceptions to the general rule of alternation of forms; having in one case a large second-form individual retaining the second-form condition after exuviation, and in the other an animal which was probably in the first-form condition remaining first-form after exuviation. It seems to me not at all improbable that No. 11 also represents one of these "abnormal" changes, being large enough to be in first-form condition, and yet again assuming the second-form just at the time when all others are first-form.

As to the microscopic condition of the testes, these specimens are not very dissimilar to others collected the same spring (Nos. 21 to 37). Of No. 34, all the lobes and the vas deferens were sectioned. The lobe is made up proximally of emptied follicles. Upon this follows an extensive zone of spermatocytes, many of them in active mitosis. The distal end of the lobe is occupied by the spermatogonial zone, which is composed of only a few follicles in one of the lobes. The vas deferens is filled with spermatozoa. Of No. 35, two lobes and the vas deferens were sectioned. In this specimen the posterior lobe is very much larger than either of the anterior lobes, but, so far as our present consideration is concerned, this seems to me to be of no great significance. The condition of the elements is very similar to that of No. 34. The vas deferens is well filled with spermatozoa. In both of these specimens we notice a predominance of spermatocytes. The relative extent of the spermatocytes as compared with the other zones is, with the exception of the one lobe of No. 34 mentioned above, not so great as in the one lobe of No. 37 which was examined. With the exception of the proportionately greater extent of the spermatocyte zone, No. 37 is very similar to Nos. 34 and 35.

Faxon, in his paper on "Dimorphism," says: "I will add that the males of extraordinary size which I have seen are all of the 'first-form.' Do these very old individuals cease to molt? Do they become permanently capable of reproduction?" My observations, so far as they extend, confirm those of Doctor Faxon. Having seen some very large secend-form males of both *C. virilis* and *C. immunis*, I must add, however, that this observation is true of only the extraordinarily large individuals. While such a hypothesis seems not at all unreasonable, I should like to examine a much larger series of material than I have yet had the opportunity of doing before I say that the males reach a permanently first-form condition. It seems to me improbable that the old individuals should cease to molt, but not at all improbable that they should continue in the same form after molting.

Doctor Faxon suggests[9] that Doctor Hagen's method of designating the two phases is not so happy as might be desired.

It would, perhaps, be better if the terms were just reversed, and the male in the condition to approach the female were called form II, since that designated by Hagen as form II is the form in which we first find the animal. While it is not at all descriptive, I can see, other than that mentioned above, no serious objection to Hagen's terminology, especially since it is so well established in the literature. It surely is very convenient, while I am not at all sure that a descriptive term which would not be cumbersome could be easily found.

No dimorphism in the males has been observed in *Astacus*, nor, so far as I have been able to learn, has any indication of it been found in any other genus of the Astacidæ, unless it be in the subgenus *Cambaroids*, where Faxon[10] suspects the presence of two forms of the male, as in *Cambarus*. Should this be found to be true, it would certainly be of great interest from a phylogenetic point of view. It must be borne in mind, however, that the Parastacine genera have not been nearly so thoroughly studied as those of the Potamobine.

A fact which I believe has not heretofore been considered in the literature on the dimorphism of *Cambarus* nevertheless seems to me significant. In *Astacus*, according to Chantran,[11] after the third year the males molt twice, first in June and July, afterwards in August and September, and the females once, from August to September, annually. According to Huxley,[12] copulation takes place immediately after *the completion of ecdysis*, in the early autumn. It is to be observed that if the alternation of forms in *Cambarus* noticed by Faxon occurs regularly year after year, which my observations tend to prove for both *C. immunis* and *C. virilis*, the parallel between the two is quite striking; the spring ecdysis of *Astacus* corresponding to that which brings *Cambarus* into the second-form after copulation, while the autumn ecdysis of *Astacus* corresponds to that which brings *Cambarus* back into the form in which it is ready to approach the female.

Neither Hagen's nor Faxon's material was in condition, having lain so long in alcohol, for a microscopic determination of the condition of the contents of the testis. My object in this study has been to supply observations on this point, hoping, by careful comparison

9. Faxon, "On so-called Dimorphism," etc.

10. Faxon, Monograph, p. 227.

11. Chantran, S. (1) "Observations sur la formation des pierres chez les écrevisses," Compt. Rend., t. 78, pp. 665–667. (2) "Sur le mechanisme de la dissolution intra-stomacale des concrétions gastriques des écrevisses," Compt. Rend., t. 79, pp. 1230, 1231. (3, 4) "Observations sur l' histoire naturelle Ecræsses," Compt. Rend., t. 69 and 73.

I have not seen these papers, but make the statement on the authority of Dr. C. L. Herrick, "The American Lobster," Bull. U. S. Fish Com., vol. XV (Washington, 1896), and Huxley (T. H.), "The Crayfish." —J. A. H.

12. Huxley, loc. cit.

of the sexual organs, to get some idea of the relation of the reproductive elements to the physical condition of the animal, and in this way come a little nearer to the determination of the true significance of the occurrence of the two forms.

As the title indicates, I do not intend this as a final paper, there being many important points yet to be ascertained before this interesting problem is fully solved. I feel, however, that, in addition to the general survey of the subject, the question, the answer to which was the original subject of the investigation, has been definitely and conclusively answered, and that the results obtained are of sufficient interest to warrant their appearance here, even before other points which have been suggested in the course of the work are decided.

My material was fixed in Flemming's fluid, sometimes with a varying amount of acetic acid, in hope of counteracting the tendency to a vacuolation of the cytoplasm during the process of division, embedded in paraffin, and sections prepared by the usual cytological methods. Heidenhein's iron-hæmatoxylin and the safranin-gentian-violet-orange-G methods were used principally as staining reagents.

I wish to express here my gratitude to Prof. C. E. McClung and Mr. W. S. Sutton, of the department of zoology, University of Kansas, where the work was done, for useful suggestions.

It will be observed that in comparing the condition of the testes of different individuals, I have frequently used some qualifying term; as, for example, "Condition about the same as No. ——." This course seemed necessary to strict accuracy; for while, so far as the essential parts are concerned, they may be alike, it must be borne in mind that considerable individual variation is to be expected. Various causes affect the relative development of the germ-cells in different individuals. In *Cambarus*, the greatest variation occurs in the general form of the testis—a condition which would imply considerable variation in the relative shape and arrangement of the different germ-cell zones. The normal testis is three-lobed—two anterior and one posterior; yet those which have become almost completely four-lobed through the division of one of those already existing are not at all uncommon.

The following table shows the condition of the testes of a number of individuals of the two forms. Usually but one lobe was examined; however, in cases where more than one lobe was sectioned, the condition was usually found to be essentially the same. It will be noted that some of the material is not in the best condition, having been prepared under unfavorable circumstances. I might say, however, that in no case have conclusions been even suggested from poor sections which seemed in any important way different from other preparations with which they were compared. The greater part of my

material is, I believe, in as good condition as that upon which many of our cytological papers are based.

No. 1. *C. immunis.* F. I. About two inches long. August 24, 1900.

One lobe sectioned. At the proximal end are a few emptied follicles and more with mature spermatozoa. Also various stages of spermatid transformation, the earlier stages being for the most part towards the distal end. The spermatids extend somewhat more than one-half the length of the lobe. Then follow spermatocytes; and finally an area of spermatogonia, about one-sixth the length of the lobe in width. An occasional division figure is seen among these spermatogonia.

No. 2. *C. immunis.* F. I. About two inches long. July 27, 1900.

Sections not in plane to show regions to best advantage, but condition seems to be about same as No. 1.

No. 3. *C. immunis.* F. II. About two and one-half inches long. August 2, 1900.

All lobes sectioned. Sections of anterior lobes not perfect. One of anterior lobes seems to have an unusually large number of spermatogonia. Condition otherwise seems to be about same as No. 1.

No. 4. *C. immunis.* F. II. Size of individual not recorded; probably about two inches long. Still slightly soft from exuviation.

Only one lobe sectioned. With the exception of a little different appearance of the spermatogonia, which, from comparison with other material, seems to me to be unimportant in this connection, this seems to agree exactly with No. 1.

No. 5. *C. immunis.* F. I. About two inches long. August 24, 1900.

One lobe sectioned. Proximal end shows follicles with mature spermatozoa. Farther back are seen follicles containing various stages of spermatid transformation; then follow spermatocytes and finally spermatogonia. Condition practically same as No. 1. Vas deferens contains a considerable number of spermatozoa.

No. 6. *C. immunis.* F. I. About two inches long. August 24, 1900.

Only one lobe sectioned. In about same condition as No. 1.

No. 7. *C. immunis.* F. I. About two and one-half inches long. August 31, 1900.

One lobe sectioned. Conditions about the same as No. 1. A section through the vas deferens shows the presence of a considerable number of spermatozoa.

No. 8. *C. immunis.* F. II. About three to three and one-half inches long. August 24, 1900.

One lobe sectioned. Condition practically identical with No. 1.

No. 9. *C. immunis.* F. II. About two and one-half inches long. August 31, 1900.

One lobe sectioned. Condition almost exactly same as that of No. 1.

No. 10. *C. immunis*. F. II. About two and one-half inches long. August 31, 1900.

One lobe sectioned. Condition about same as No. 1.

No. 11. *C. virilis*. F. II. Perfectly soft from shedding. A little over two inches long. September 4, 1900.

One lobe sectioned. Seems to be abnormal. There are present, however, almost mature elements, spermatids, spermatocytes, and spermatogonia.

No. 12. *C. immunis*. F. II. About two inches long. August 24, 1900.

One lobe and vas deferens sectioned. Condition of lobe practically same as No. 1. Vas deferens contains many spermatozoa.

No. 13. *C. immunis*. F. I. Good-sized individual. Probably two and one-half or three inches long. Collected in burrow, October 13, 1900.

One lobe and vas deferens sectioned. Proximal part of lobe made up of emptied follicles and those yet filled with mature spermatozoa. Farther back are seen spermatids in various stages of transformation, some of them quite early. A few follicles with spermatocytes are noted. Bordering immediately on the spermatid region, or upon the scattered follicles of spermatocytes, is seen the distal region of spermatogonia, in which a division figure is occasionally to be noted.

No. 14. *C. immunis*. F. I. About two and one-half inches long. August 21, 1900.

Material so badly oriented and broken up in preparation that an *exact* determination of the different regions is impossible. Spermatozoa, spermatids, spermatocytes and spermatogonia are found. Apparently, it is practically the same condition as No. 1. Vas deferens shows considerable number of spermatozoa.

No. 16. *C. immunis*. F. I. About two or two and one-half inches long. August 21, 1900.

One lobe examined. Condition about same as No. 1.

No. 17. *C. immunis*. F. II. About two inches long. August 24, 1900.

One lobe sectioned. Condition practically same as No. 1.

No. 18. *C. immunis*. F. II. About two and one-half inches long. August 2, 1900. Still fairly soft from shedding.

Condition practically same as in No. 1.

No. 20. *C. virilis*. F. I. About two and one-half inches long. Collected in ice-cold water in creek, January 18, 1901.

Sections not longitudinal, and so arrangement of regions is uncertain. Most of the follicles are filled with mature spermatozoa; in some few the spermatozoa are apparently not quite mature, not being massed together at the center. Follicles containing spermatocytes, and a greater number containing spermatogonia, also occur. The vas deferens contains a good many spermatozoa, but is not nearly full.

No. 21. *C. immunis*. F. I. About two or two and one-half inches long. March 19, 1901.

All lobes of testis sectioned. Proximal ends made up of emptied follicles. Beyond these are some still containing apparently the original number of spermatozoa of the preceding season. A few follicles are filled with large primary spermatogonia. An occasional follicle contains spermatocytes in fine spireme condition. Those of the distal end contain spermatogonia, among which an occasional division figure is to be seen. The vas deferens is well filled with spermatozoa.

No. 22. *C. immunis*, F. I. Two and one-third or three inches long. March 19, 1901.

Two lobes and vas deferens sectioned. Is in practically same condition as No. 21.

No. 23. *C. immunis*. F. I. About two and one-half inches long. March 22, 1900.

Two anterior lobes and vas deferens sectioned. Condition practically same as in No. 21.

No. 24. *C. immunis*. F. I. About three inches long. March 22, 1901.

Vas deferens examined. Well filled with spermatozoa.

No. 25. *C. immunis*. F. I. About two and one-half inches long. March 24, 1901.

Somewhat broken up in preparation. Condition about same as No. 21. Spermatocytes not common. Follicles do not contain so many spermatozoa.

No. 26. *C. immunis*. F. I. About two and one-fourth inches long. March 27, 1901.

Two lobes sectioned. Condition largely same as No. 21. No spermatocytes were noticed and no follicles still containing any considerable number of spermatozoa. Spermatogonial region more extensive than in No. 21.

No. 27. *C. immunis*. F. I. Early May, 1900.

Sections rather poor. Lobe seems to be made up of the proximal area of emptied follicles and a large distal area of spermatogonia, among which occasional division figures are to be observed. The vas deferens is well filled with spermatozoa.

No. 28. *C. immunis*. F. II. April, 1900.

Sections poor. Conditions practically same as in No. 27. Vas deferens well filled with spermatozoa.

No. 29. *C. virilis*. F. II. May 5, 1900.

Sections poor. Conditions probably much the same as in Nos. 27 and 28.

No. 30. *C. virilis*. F. II. May 5, 1900.

Condition largely same as the three preceding. In Nos. 27 to 30, taken in the spring of 1900, we find essentially the same conditions, both in *C. immunis* and *C. virilis*, as those observed in No. 21.

No. 31. *C. immunis*. F. II. About three inches long. Slightly soft from exuviation. April 20, 1900

Two lobes sectioned. Condition same as No. 26.

No. 32. *C. immunis*. F. II. About two and one-half inches long. Very soft from exuviation. April 21, 1901.

One lobe sectioned. Condition seems to be about the same as No. 36. Vas deferens well filled with spermatozoa.

No. 33. *C. immunis*. F. I. About two and one-half inches long. Did not seem to be nearly ready to exuviate. April 21, 1901.

One lobe sectioned. Condition much the same as in No. 31. Vas deferens well filled with spermatozoa.

No. 34. See body of paper, pages 50 and 51.

No. 35. See body of paper, pages 50 and 51.

No. 36. *C. immunis*. F. II. About three inches long. Kept in laboratory in second-form condition eight days. May 5, 1901.

Two anterior lobes sectioned. Condition much the same as in No. 21. Spermatocytes perhaps somewhat more numerous, and spermatogonial region more extensive.

No. 37. *C. immunis*. F. II. About three inches long. Had been kept in the laboratory. Had been in second-form condition at least ten days. May —, 1901.

One lobe sectioned. In this specimen nearly all the spermatogonia have gone over into early spermatocytes. The region of spermatocytes is proportionately considerably larger than the spermatogonial region in any of the above-mentioned material. The vas deferens is well filled with spermatozoa.

From an examination of Nos. 1 to 18 it will be seen that no constant differences can be demonstrated between the testes of first- and second-form males collected in the late summer. The material examined includes specimens yet comparatively soft from exuviation as well as those which have apparently been in first- or second-form for a considerable length of time. An examination of Nos. 21 to 37 shows that in the spring ecdysis, as well, no definite difference which might determine the time of the change of form is to be observed.

The list of material described above tends to show that the main part of the regeneration of the male sexual elements takes place between the spring exuviation, in which the animal assumes the second-form, and late in August, and that during the latter portion of this period the animal may be in either of the forms. The later stages of regeneration take place, so far as I have been able to observe, in exactly the same manner, whether the animal is first- or second-form.

While advancing this theory rather tentatively, it seems to me that from the evidence at hand we must conclude that the second-form represents the period in which the greater part of the regeneration of

the sexual elements takes place, but that the limits of this period are not definitely determined by the condition of development of the germ-cells. In other words, the *sexual* condition of the animal is not the only determining factor to be taken into consideration. This is well shown by the variation observed in the testes of individuals in the same form as well as by the similarity of those from individuals of different form, and also by the occurrence of individuals in which the alternation of forms does not regularly occur.

SUMMARY.

The principal points of this paper may be briefly summarized as follows:

1. The alternation of forms, which Faxon observed for *C. rusticus* Girard and *C. propinquus* Girard has been shown for *C. immunis* Hagen, and without doubt occurs in *C. virilis* Hagen.

2. Exceptions to this alternation of form are to be found in adult indviduals.

3. No difference can be detected between the testes of first- and second-form males taken at the same time of year, either as regards gross anatomy or microscopic structure. So far as the presence of sexual elements is concerned, therefore, the second-form male is as capable of copulation as is the first-form.

4. The second-form condition probably represents, in the adult individual, the period in which the greater part of the regeneration of the sexual elements takes place.

5. The parallel between the first- and second-form males in *Cambarus* and the spring and fall exuviation of *Astacus* is probably not without significance.

LABORATORY OF ZOOLOGY AND HISTOLOGY,
UNIVERSITY OF KANSAS, MAY 20, 1901.



SPERMATOGENESIS OF THE MYRIAPODS.

Notes on the Spermatocytes and Spermatids of Scolopendra, I.

BY M. W. BLACKMAN.

With Plates V, VI, VII.

I.—INTRODUCTION.

IN this paper it is my purpose merely to describe briefly certain appearances observed in the spermatocytes and early spermatids of *Scolopendra*, leaving the complete spermatogenesis to be treated much more at length in a future paper, which I hope soon to have ready for publication.

The terminology employed in this article will conform as closely as possible to that which has been used in other papers coming from this laboratory (by McClung[1] and Sutton[2]), but from the very extraordinary character of my material, several new terms will necessarily be introduced. These I have endeavored to make as descriptive as possible of the appearances designated.

I wish to express my gratitude to Prof. C. E. McClung for advice and assistance in carrying on this work. My thanks are due also to Mr. W. S. Sutton for collecting the material upon which these observations were made, and for various suggestions at different times.

II.—MATERIAL AND METHODS.

The material upon which these observations were made was collected in June, 1900, in Russell county, Kansas, by Mr. W. S. Sutton. The preceding spring, however, some material from other forms of myriopods was obtained by Prof. C. E. McClung. This included several species of both diplopods and chilopods. However, as the form collected by Mr. Sutton proved more favorable, the greater part of these observations was made upon it.

The species in question is the large reddish-brown *Scolopendra*,

1. McClung, C. E., 1899: "A Peculiar Nuclear Element in the Male Reproductive Cells of Insects," Zool. Bull., vol. II, No. 4. Also, same author, 1900: "The Spermatocyte Divisions of the Acrididæ," Kan. Univ. Quar., vol. IX, No. 1.

2. Sutton, W. S., 1900: "The Spermatogonial Divisions in Brachystola magna," Kan. Univ. Quar., vol. IX, No. 2.

found abundantly in the Southwest. It is a large centipede, about four inches long and four lines across.

Each part of the paired testes, which lie in the dorsal region, consists of a number of divisions. As a rule these divisions are made up of two follicles, tapering toward each end, placed side by side in such a way that they roughly resemble a diatom. Occasionally, however, they are single; *i. e.*, they consist of only one follicle. The lobes are connected to the vas deferens by a duct attached to one end of each follicle.

The testes which I have thus far examined are far advanced in development and contain very few spermatogonia. The other generations of the germ-cell are, however, very well represented.

The younger spermatocytes, with a few spermatogonia, are arranged upon the periphery of the follicle, while within are the later spermatocytes and spermatids; and, in the central portion, are large masses of later spermatids and spermatozoa in various stages of formation. In most of the testes examined the spermatozoa are much more numerous than any of the other cell generations.

In the manipulation of this material two fixing reagents were used: Flemming's chrom-osmium-acetic mixture and Gilson's nitro-acetic-sublimate mixture. Both of these fixatives gave excellent results, but Gilson's fluid was the better. The fixation with this was perfect, there being no shrinkage or other apparent distortions.

Indeed, the only disadvantage of the Gilson fixative is the difficulty experienced in the later manipulation. When embedded in paraffin, the material is so soft and spongy that it folds upon the knife in cutting. This difficulty was obviated in the following manner: The material was gradually carried up to absolute alcohol, from which it was transferred to celloidin and allowed to infiltrate thoroughly. Then the celloidin was allowed to evaporate gradually, until it was of the consistency of thick cream. Finally all the surplus celloidin was removed, and the mass was cleared for several hours in chloroform. This accomplished, the specimen was infiltrated with paraffin and embedded in the same substance. The material cut perfectly, without any wrinkling or distortion of the sections, and without any of that shrinkage of the cells which often occurs when the ordinary paraffin method is employed.

In staining, a considerable number of reagents were employed. The best results were obtained with Heidenhain's iron-hæmatoxylin, used either alone or in connection with Congo red; Kernschwarz; and the Flemming three-color stain. Fair results were obtained also with Bismarck brown, methyl-green, cyanin, and Auerbach's methyl-green and acid fuchsin.

III.—OBSERVATIONS.

1. *The Spermatocytes.* The spermatocytes, as they arise from the telophase of the last spermatogonial division, are very small in comparison with the truly enormous size attained by them later. Even in this stage their size varies somewhat, but the average diameter is not more than ten micra. At this time the nucleus fills nearly the entire body of the cell, and its chromatin is in the form of a number of short, granular segments. (Fig. 1.)

These segments, by their disintegration and subsequent union, form the spireme seen in a later stage. (Fig. 2.) This spireme is similar in all respects to that found in the spermatocytes of insects at the same stage of the prophase.

The resemblance of the spermatocytes of myriapods to those of insects is still further emphasized by the presence, within the nuclear cavity, of that peculiar chromatic element known as the accessory chromosome.

As is the case in insects, this element lies immediately against the nuclear membrane. It stains intensely with all chromatin reagents employed, and in other ways behaves as does the accessory chromosome of insects. It is peculiar, however, in that it is approximately spherical in form.

At this stage, the cytoplasm, although much more voluminous than in the spermatogonia, is relatively small in amount as compared with what it becomes later. It is finely reticular in structure and, as far as observed, contains no centrosome or idiozome. Yolk material is sometimes present in small quantities.

When the cell has reached the stage represented in fig. 2, the chromatin spireme gradually breaks down, and the nucleus is filled with a looser, less densely staining reticulum, as represented in fig. 3. This reticulum continues to become finer and less dense, until the cell finally reaches the stage represented in fig. 4, where the nuclear cavity is filled with a beautiful regular network composed of faintly staining fibers. Most of the cells remain in this condition until the active prophase begins with the formation of the tetrads. Some, however, go still farther, and in these the reticulum of the nucleus could not be distinguished from that of the cytoplasm were it not for the nuclear membrane enclosing it. These cells are, moreover, larger than the ordinary ones at this stage.

Meanwhile the accessory chromosome has undergone very marked changes. It has increased in size much out of proportion to the rest of the nucleus, as is shown in fig. 4. It is still approximately spherical in form and shows the same affinity for chromatin stains which is characteristic of it in preceding stages.

Synchronously with these changes in the character of the nucleus, the cell has undergone a truly remarkable increase in size. In the early spireme stage the average diameter of the cell was about ten micra; now the average diameter is thirty-five micra, and the largest cells reach an enormous size, their diameter being about ninety micra. By this extensive growth the cytoplasm has increased in amount much more than has the nucleus (fig. 4), but still shows its finely reticular structure. Embedded in the meshes of this network are large masses of yolk material. This food substance generally forms a zone surrounding the nucleus, the inner portion being but little denser than the cytoplasm, while the outer portion, which is often broken up into uneven projections, stains much more densely. Occasionally the deutoplasm is not arranged in the manner described, but is distributed irregularly around the nucleus in masses of various sizes. At this stage I have been unable to find any centrosome or attraction sphere.

As will be seen from the plates, the spermatocyte, during this dif fuse reticular stage, approaches very nearly the egg type. Indeed, this similarity is so striking, that upon a superficial examination, I was inclined to believe that these cells were really egg-cells, and, as various stages of the male germ-cells were also present, that the animal, contrary to general belief, was hermaphrodite. However, upon further study, this first impression was soon found to be erroneous, as the true character of the cells was then conclusively apparent.

So far as I have been able to learn, male cells so very similar to the egg-cells have never been described. For that stage of the prophase in the spermatocytes of *Scolopendra* I wish to propose the name of the *pseudo-germinal-vesicle stage.* At this time the nucleus is, in appearance, identical with the typical germinal vesicle of the egg. It is small in proportion to the amount of cytoplasm, and is situated somewhat eccentrically. The reticulum is very similar in appearance to that of the immature ovum, and the accessory chromosome resembles very closely the germinal spot of the female element. Indeed, the later behavior of the accessory chromosome is very much like that of the germinal spot in those eggs in which the chromosomes are derived from this element.

From the diffuse germinal vesicle stage described, the chromatin reappears as a number of diffuse masses. These quickly assume a form identical with that of the typical insect tetrad, described by Paulmier[3] in *Anasa*, and by McClung[4] in *Hippiscus.* The process of the formation of these tetrads is so rapid that they often appear to arise from the diffuse pseudo-germinal-vesicle stage as well-defined

3. Paulmier, F. C. 1899: "The Spermatogenesis of Anasa tristis," Jour. Morph., vol. XV. Supplement.

4. McClung, C. E., 1900, loc. cit.

tetrads, without having passed through any of the intervening stages. Several of these tetrads may often be seen in a nucleus, and among them are flaky masses of chromatin from which the rest are to be formed. In these nuclei the accessory chromosome is always irregular in form and granular toward the outside, showing that the substance from which the tetrads are formed is derived from its substance. These tetrads assume all the typical forms described for them in *Anasa* and *Hippiscus* (fig. 6), and, as in the cells of those animals, may all be referred to a single type, their apparent diversity of form being caused either by the point from which they are seen or by a slight natural modification.

The tetrads, as they first appear, are rather elongated, the longitudinal split being much more pronounced than the transverse one. At first they are composed of rather coarse granules or flakes of chromatin loosely arranged, but, as the cell approaches division, the granules become finer and arrange themselves in masses, which stain much more densely with chromatin stains. (Figs. 6, 7.)

It is at about this time that the centrosome appears. (Fig. 7.) It is first to be seen in the yolk material, which at this stage is collected in a large, irregular mass at one side of the nucleus. The centrosome is a rather prominent dumb-bell-shaped body contained in a clear space, fairly well differentiated from the surrounding deutoplasm. At this stage it is not nearly so large as it becomes later, in the prophase and in the metaphase.

From this time the movements of the centrosome can be traced clearly, up to the telophase of the succeeding division. The dumb-bell-shaped figure elongates and finally constricts (fig. 8), forming two spherical bodies. Astral radiations then appear and the centrosomes move toward the nucleus and finally come to rest upon the nuclear membrane. (Fig. 9.) The astral radiations become more marked and the centrosomes move slowly apart upon the membrane. (Figs. 9, 10, 11, 12).

When they have reached points about 100 degrees apart, the nuclear membrane begins to disappear. That part over which the centrosomes have not passed in their migration is the first to be dissolved, while the portion between the centrosomes persists for some time, as is shown by the numerous cells in which it is still to be found. (Figs. 11, 12.) At this stage the astral rays are more marked than at any preceding time, but are not so prominent as they become later, in the metaphase and anaphase.

While these phenomena have been occurring, the tetrads have also changed. They have lost their granular character and ragged outline, have become much more homogeneous, and have assumed an approximately spherical form. They can no longer be distinguished

from the accessory chromosome, which, on account of its greater density and its nearly spherical form, could be easily observed up to this time.

Since the pseudo-germinal-vesicle stage, the accessory chromosome has undergone several interesting changes. As we have seen, it is then remarkable for its large size and strong affinity for chromatin stains. In the active prophase following this, while the chromatin is collecting in diffuse, flaky masses preparatory to tetrad formation, this element decreases much in size, and at the same time its outline becomes very irregular. In a later stage, shown in figs. 5, 9, the contour of this element has again become regular; it has resumed its spherical form, and has diminished in size, until now it is no larger than a chromosome in the metaphase of the first spermatocyte division. It goes to the equatorial plate without previously showing any sign of division.

I can see but one plausible explanation for the behavior of the accessory chromosome in the pseudo-germinal-vesicle stage and in the late prophase succeeding. While the nucleus is in the diffuse condition, it would seem that the accessory chromosome acts as a storehouse for practically all of the chromatin of the cell, or, more properly, serves as a center around which the chromatin becomes condensed. As has been mentioned before, the later behavior is very similar to that of the germinal spot in some eggs.

With the disappearance of the nuclear membrane, mantle fibers are seen connecting each centrosome with the chromosomes. (Fig. 11.) The chromosomes heretofore distributed irregularly throughout the nuclear space are drawn into the equatorial plate, and a very short spindle is formed. (Fig. 13.)

Later the centrosomes move apart some distance, until the cell presents the appearance represented in fig. 15. By this movement the shape of the chromosomes is altered somewhat, and they now show signs of division. At this stage the astral rays can be seen, connecting the centrosomes with the cell membrane. They are very distinct, and there is no question but what they really extend from the centrosome to the cell membrane. From their separation upon the nuclear membrane, up to this time, the centrosomes have been of an irregular spherical form. Now, however, their shape is changed, and they appear as rather large, cone-shaped masses, with their apices turned toward the equatorial plate. (Figs. 15, 16.) At no time is the outline of the centrosome exactly spherical.

When the cell has reached this stage a very unusual thing occurs. By the contraction of the astral rays attached to the cell membrane the centrosomes are drawn still farther apart, and take up their position at points a short distance from the cell membrane. (Fig. 16.)

The peculiar thing is that the mantle fibers no longer converge toward the centrosomes, but to the points which the centrosomes occupied before their last migration. From this center of convergence, which I will call *the apical point*, parallel strands of linin extend to the centrosome. These linin bands are, I believe, but the continuation of the mantle fibers. Radiating fibers are now seen extending out into the cytoplasm, from the apical point as well as from the centrosome proper, although those from the latter are much more distinct. The astral rays connecting the centrosome and the cell membrane are still more pronounced at this stage. The centrosome is still conical in form.

The centrosomes again move apart and take up their final position upon the cell membrane, where they are flattened out into rather large hemispherical bodies. Well-marked astral radiations still extend out into the cytoplasm. By these last movements of the centrosomes the chromosomes have been drawn apart, and, by the synchronous contraction of the mantle fibers, have been drawn toward the poles, and come to rest at the point at which the mantle fibers converge, where they are arranged in a densely packed mass. (Fig. 17.)

When the chromosomes have taken up their final positions the cell-walls begin to constrict. As this proceeds the fibers connecting the two daughter masses of chromatin are crowded together into a bundle, which finally presents the appearance represented in fig. 20. A midbody, or zwischenkörper, is formed at the point where the constricting wall approaches this bundle of persisting fibers. This is composed of a number of small, darkly staining bodies about equal in number to the chromosomes. These bodies are arranged close together upon the periphery of the bundle in such a manner as to form a ring. (Fig. 20.) A similar appearance has been described by McGregor[5] in *Amphiuma*. In *Scolopendra*, however, this ring does not persist, as is the case in *Amphiuma*.

The division figures of the second spermatocytes are very similar to those of the first. Indeed, the two generations can be distinguished only by the character of the chromosomes. A short spindle is formed (fig. 21), and the cell undergoes changes similar to those in the first spermatocytes. In the early telophase the cell presents the appearance represented in fig. 22. The daughter masses of chromatin are smaller than in the corresponding stage of the first division. The chromosomes are so closely massed together that the outlines of the individual elements cannot be distinguished, although, of course, they do not lose their individuality. Connecting fibers extending from one daughter plate to another are plainly visible, and astral radiations

5. McGregor, J. H.: "The Spermatogenesis of Amphiuma," Jour. Morph., vol. XV. Supplement.

are also to be seen proceeding out into the cytoplasm. The centrosomes are rather large, hemispherical bodies, in close contact with the cell-wall. Midway between the daughter plates the cell membrane shows evident signs of constriction.

In a later stage, shown in fig. 23, the cell membrane constricts in the plane of division, and, as this advances toward the center of the cell, the fibers persisting between the daughter masses of chromatin are crowded together so as to form the well-known spindle remains. A midbody is formed, as in the telophase of the first spermatocytes. The centrosomes still persist, although they have diminished in size, and the astral radiations have disappeared. They are still to be found in close contact with the cell membrane at the ends of the cell furthest from the plane of division. The cytopasm has resumed its reticular character. The last trace of yolk material disappeared at about the time of the disintegration of the nuclear wall in the first spermatocytes (fig. 12), and none has yet reappeared. The chromosomes have become separated from each other and are irregularly distributed throughout the nuclear vesicle, which at this time is surrounded by no well-defined membrane. At this stage they still preserve their regular outlines.

2. *The Spermatids.* The spermatids, as they arise from the last maturation division, are rather small cells, with the nucleus placed somewhat eccentrically. Fig. 24 represents one cut through the short diameter of the cell. The cell membrane is fairly well defined and the nucleus is spherical in shape, as usual. At first the chromosomes are regular in outline but soon break down, and the nucleus is occupied by a number of irregular chromatin masses. Linin fibers can be seen connecting the chromatin masses.

When the cell has reached this stage a very remarkable thing happens. The nuclear wall sends out a projection upon one side (fig. 25), and into this protuberance, which is still surrounded by the well-defined nuclear membrane, several of the irregular chromatin masses pass. These are still connected with each other, and with the other masses of chromatin in the nucleus, by linin fibers. The number of these masses which pass into this bud or protuberance varies somewhat, but is generally two or three.

This protuberance soon shows signs of constricting off from the main body of the nucleus (fig. 26), and at this period the nucleus presents much the appearance of a yeast cell during the process of budding. This body, for which I would propose the name of *itomere* (the word indicating the behavior of this body), becomes constricted off from the nucleus, and, moving out through the cytoplasm, finally passes through the cell membrane and is extruded from the cell. Various stages in the migration of this peculiar structure are repre-

sented in figs. 25 to 30. In fig. 26 the itomere has nearly constricted off from the nucleus. In fig. 27 it has left the nucleus and is seen free in the cytoplasm, surrounded by a rather well-defined membrane. The nuclear membrane remains open at the point from which it was constricted, and the course the itomere has taken through the cytoplasm is plainly visible. In fig. 28 it is seen extending from the nucleus, with which it is still connected, to the cell membrane. In fig. 28 it has reached the cell membrane, and in fig. 29 has been extruded and the membrane has apparently closed behind it.

In all these cases the nucleus has remained open, and the pathway left by the itomere in its passage through the cytoplasm can be plainly distinguished. The best stain for demonstrating the stages just described is obtained by using Heidenhain's iron-hæmatoxylin in connection with Congo red. The chromatin, as usual, takes on a dense black stain, that of the nucleus and that of the itomere staining precisely alike. The ground substance of the cytoplasm takes on a transparent red stain, against which the fibers forming the reticulum stand out plainly. The pathway left by the itomere stains a little darker red than the groundwork of the reticulum.

The budding process and the extrusion of the itomere is accompanied and succeeded by a great increase in the size of the cell, as can plainly be seen by consulting the plates. At first this growth is more marked in the cytoplasm (figs. 24–27), but later the nucleus also grows, although not in proportion to the cytoplasm. (Figs. 29–31.) As far as I am informed, such a remarkable increase in the amount of cytoplasm has never been described in the spermatids.

During this growth period masses of deutoplasm are present in the cells in more or less abundance. The first evidence of yolk observed in the spermatids appears at the time of the protrusion of the itomere.

Thus the formation and extrusion of the itomere seem to have some connection with the succeeding growth of the cell and the appearance of yolk substance, as well as with the origin of another structure concerning which I shall speak later.

I wish now to return to a consideration of the behavior of the centrosome. The last time the centrosome was mentioned it was a rather small, darkly staining body, in close contact with the cell membrane, upon that side of the cell farthest from the plane of division. At this time no radiations are to be seen proceeding from it and it is surrounded by no idiozome or attraction sphere. From this place the centrosome can be traced for a time, but is lost. Later it reappears, and from this time can be traced to its final position in the middle piece of the spermatozoön. It leaves its place upon the membrane and, up to a time when the budding process is well under way, may be seen at various places in the cytoplasm. There it disappears and is not again

seen until the stage represented in fig. 30 is reached, when it has taken up its position near the nucleus, at one side of the opening in the nuclear membrane. At the time of the disappearance of the centrosome, masses of deutoplasm have become abundant in the cell, and it is very probable that this element is merely concealed by one of these and that it will be found on further study.

As before stated, the pathway left by the itomere in its passage through the cytoplasm can be easily distinguished. As the cell increases in size, this, instead of becoming more faint, as one might expect, gradually becomes plainer and more easily distinguishable (figs. 29–33), until, in the stage represented in fig. 34, it stands out as a densely staining black line—the axial filament. This is formed, not by an outgrowth or elongation of the centrosome, as has been described for other objects, but by the collection and condensation of the fibers of the cytoplasmic reticulum. In earlier stages (fig. 32), a cross-section of the pathway left by the itomere shows a rather diffusely staining area, toward which the fibers composing the reticulum converge as toward a centrosome. At this stage, however, the centrosome can be clearly distinguished at a point near the nucleus and at one side of the position subsequently occupied by the axial filament. Later, it moves directly into the course of the future axial filament, which, at this period, stains more densely, and, although still somewhat granular and indefinite in appearance, stands out much more distinctly than at any previous time. (Figs. 33, 34.)

While this is taking place the cytoplasm becomes vacuolated in the region surrounding the axial filament. The large, rather elongated vacuoles extend with their longer diameters approximately parallel to the course of this structure.

The significance of this vacuolation appears to be in the fact that the previously fine reticulum is being broken down and reformed into fibers extending parallel to the axial filament, thus leaving large clear spaces in the cytoplasm. In later stages these fibers become collected and condensed, and in the mature spermatozoön, although they still preserve their individuality, cannot be distinguished from each other without the aid of maceration. The origin of the axial filament in *Scolopendra* from the fibrillar reticulum of the cytoplasm agrees with the discoveries by Ballowitz[6] of the fibrillar character of this element in spermatozoa. He describes it as being made up of a large number of parallel fibrillæ.

The axial filament being thus definitely formed, farther changes consist in its elongation, and this continues until it is several hundred micra in length. Its later growth is accompanied by a corresponding

6. Ballowitz, E., 1891: "Weitere Beobachtungen uber den feineren Bau der Saugethierspermatozoen." Zeitschrift fur wissenschaftliche Zoologie. Bd. LII.

lengthening of the cell. When the spermatid has reached the stage shown in fig. 35, the cell outline in the region posterior to the nucleus is very difficult to follow.

An acrosome first appears at this stage, at the side of the nucleus opposite the base of the axial filament. This, at this time, is a spatulate vacuole, which shows no affinity for chromatin stains. In later stages this body increases much in size and stains weakly with iron-hæmatoxylin. (Figs. 38, 39.)

Concerning the later changes in the spermatid I will say nothing in this paper, but will merely show a few of the observed stages by drawings.

IV.— COMPARISON OF LITERATURE.

The Accessory Chromosome.—Until quite recently the true nature of the accessory chromosome was not understood, and by various writers it has been classified among that very ill-defined group of bodies, the nucleoli. It was first observed by Henking,[7] and by him called a nucleolus. Later observers, Vom Rath,[8] Wilcox,[9] Moore,[10] and Wagner,[11] have evidently had much the same understanding of its nature, as they classified it similarly. In 1898 Montgomery[12] found the same element in the testicular cells of *Pentatoma*, but evidently did not fully understand its true character, as he called it the "chromatin nucleolus."

In 1898 McClung[13] first correctly interpreted the character of this element. He described it as a metamorphosed chromosome, and to it applied the name "accessory chromosome."

In a paper which appeared the latter part of the same year, Paulmier[14] recognized its chromosomal nature and designated it the "small chromosome." This name appears to have been unfortunately chosen, as in many animals this element is the largest and most conspicuous chromosome in the cells. In his material, *Anasa tristis*, the accessory chromosome takes on the shape of a completely formed tetrad without passing through any of the preceding stages. In the first spermatocyte division it is divided along with the other chromosomes, but in the second, after remaining in the equatorial plate for some time, goes to one pole undivided.

7. Henking, H., 1891: "Ueber Spermatogenese und deren Beziehung zur Entwicklung bei Pyrrhocoris apterus." Zeitsch. f. Wissensch. Zool. Bd. XXV.

8. Vom Rath, O., 1892: "Zur Kenntniss der Spermatogenese von Gryllotalpa vulgaris." Archiv f. Mikro. Anat., Bd. XI.

9. Wilcox, E. V., 1895: "Spermatogenesis of Caloptenus femur-rubrum and Cicada tibicen." Bull. Mus. Comp. Zool., vol. XXVII.

10. Moore, J. E. S.: "On the Structural Changes in the Reproductive Cells during the Spermatogenesis of Elasmobranchs." Quart. Journ. Micr. Sci., vol. XXXVIII.

11. Wagner, J., 1896: "Beiträge zur Kenntniss der Spermatogenese bei den Spinnen." Arb. Nat. Ges., St. Petersburg, vol. XXVI.

12. Montgomery, T. H., jr, 1898: The Spermatogenesis of Pentatoma up to the Formation of the Spermatid." Zool. Jahrb. Bd. XII.

13. McClung, C. E., 1899, loc. cit.

14. Paulmier, F. C., 1899, loc. cit.

McClung,[15] in a later paper, describes the accessory chromosome as occurring in *Hippiscus*. In the spireme stage it is to be seen as a large, densely staining homogeneous body, in close contact with the nuclear membrane. In a later stage it leaves its peripheral position and takes on the appearance of a longitudinally split rod. It is divided by the first maturation mitosis, but in the second passes over bodily into one of the daughter cells. In *Scolopendra*, as far as I have observed, the accessory chromosome shows no sign of division in the prophase and goes to the equatorial plate as a spherical body.

Sutton,[16] in his article on "The Spermatogonial Divisions in *Brachystola magna*," describes the behavior of this element in the spermatogonia. He throws much stress on the individuality of this element, for, as he conclusively shows, "It maintains throughout the spermatogonial divisions, as well as those which follow, an indubitable independence, being enclosed at all stages, except those of actual division, in its own individual membrane." As I have shown, quite a different condition exists in the pseudo-germinal-vesicle stage of *Scolopendra*, for at this stage all the chromatin of the cell is condensed into one deeply staining, homogeneous mass.

Montgomery,[17] in his article on *Peripatus*, fails to find an accessory chromosome, but describes a body which behaves very much like this element. He gives at length his reasons for not considering it the "chromatin nucleus." However, I believe he is mistaken, and that the element described is, in truth, the accessory chromosome.

In comparing the accessory chromosome found in *Scolopendra* with that described by these investigators, several points of difference are observed as well as many points of similarity. Its origin, staining reaction and its behavior in the early spermatocytes are very similar to that in insects, but in its behavior in the pseudo-germinal-vesicle stage, and in the succeeding stages, it is quite different. As I have shown, it seems to act as a reservoir in which is deposited practically all of the chromatin of the nucleus. At this stage it is enormous as compared with its former size. In the later prophase, part of the chromatin forming this mass leaves the accessory chromosome and collects in diffuse granular masses, which eventually form the tetrads as described. At this time the accessory chromosome loses its regular outline and becomes granular toward the outside. When the tetrads are formed, however, it again assumes its homogeneous character and regular outline, but has decreased in size until it is no larger than the ordinary chromosome in the metaphase. It can be readily distinguished from the other chromosomes up to the time of the dis-

15. McClung, C. E., 1900, loc. cit.
16. Sutton, W. S., 1900, loc. cit.
17. Montgomery, T. H., jr., 1901: "The Spermatogenesis of Peripatus up to the Formation of the Spermatid." Anat. An. Bd. XVI.

integration of the nuclear membrane. It goes to the equator without previous sign of division.

Tetrad Formation. The typical process of tetrad formation in insects, as described by Paulmier[18] in *Anasa* and McClung[19] in *Hippiscus*, is as follows: The spireme splits lengthwise and segments into a number of rods equal to the maturation number of chromosomes. These double rods shorten, become more finely granular, and split again transversely. At this time the typical form is represented by the cross-like figures shown in the plates (figs. 5, 6, 7), although there are many modifications. These cruciform masses condense, become homogeneous, and stain more transparently.

I have already described the process of tetrad formation in *Scolopendra.* In the formation of the tetrads from the diffuse, flaky mass of chromatin arising in the pseudo-germinal-vesicle stage there seems to be no definite splitting of the segment, but the chromatin seems to collect more densely at certain areas, and thus to form the tetrad figures.

As regards the sequence of the longitudinal and cross divisions of the chromosomes, there seems to be much difference in the results of various investigators on arthropods. Several observers, among whom are Vom Rath,[20] Paulmier,[21] and Montgomery,[22] describe the transverse division as occurring first. Häcker[23] and McClung,[24] however, find that the first is the equation and the second the reduction division. McClung lays especial stress upon the importance of the later prophase of the spermatocyte in determining the sequence of the following divisions. His point seems to be very well taken, and, as in *Scolopendra,* as well as in *Hippiscus*, the longitudinal cleavage is the first one made manifest in the prophase. I believe that the first mitosis results in the longitudinal division of the tetrads.

The Budding of the Nucleus. In the male germ-cell, nothing has been described, I believe, which corresponds to that peculiar structure which I have called the itomere. In the egg-cells of various animals, however, a structure, similar in origin and, in some respects, in function, has been reported by several investigators. This is the yolk nucleus, as described by Blochmann, Scharff, Balbiani, and others.[25] In the material upon which these investigators worked, the yolk nucleus is derived from the chromatin reticulum of the nucleus

18. Paulmier, F. C., 1889, loc. cit.
19. McClung, C. E. 1900, loc. cit.
20. Vom Rath, O., 1892, loc. cit.
21. Paulmier, F. C., 1899, loc. cit.
22. Montgomery, T. H., jr., 1898 and 1901, loc. cit.
23. Hacker, V., 1897; "Ueber weitere Uebereinstimmungen zwischen den Fortpflanzungsvorgangen der Theire und Pflanzen." Biol. Cent., vol. 17.
24. McClung, C. E., 1900, loc. cit.
25. Wilson, E. B., 1900: "The Cell in Development and Inheritance."

by the process of budding. A protuberance appears upon the nucleus, is constricted off, and, passing out into the cytoplasm, serves as a center around which the food substance of the cell is formed.

Thus, although the origin is similar in some respects to that I have described for the itomere in the spermatids of *Scolopendra*, its later behavior is very different. The itomere migrates through the cytoplasm, and is cast out through the cell-wall. The movement of this structure through the cytoplasm is accompanied by the formation of yolk material and the rapid growth of the cell, but its most important function is quite different. In its migration toward the cell-wall it seems to organize the cytoplasm and to mark out the course of the future axial filament.

The Origin of the Axial Filament. Regarding the origin of the axial filament there seems to be much unanimity of opinion among the more recent investigators. In 1895 Moore[26] found that, in elasmobranchs, the axial filament is formed by the elongation of the centrosome. Quite similar results were obtained by other investigators on the elasmobranchs, and in mammals and amphibians a like origin is ascribed to this element.

As regards its formation in arthropods, Paulmier[27], in *Anasa*, speaks of the axial filament as an outgrowth of the centrosome. Whether by this he means that, beginning with the centrosome at the base of the nucleus, the cytoplasmic reticulum is progressively condensed, or whether he believes it to be formed by a mere elongation of the centrosome, as in elasmobranchs, I cannot determine.

In either case its origin does not correspond to that in *Scolopendra*. In this material it certainly is not an elongation of the centrosome, and, just as surely, is not a progressive condensation of the cytoplasmic reticulum, for at all stages all parts of the axial filament stain exactly alike. In my observations I have attempted to explain the true origin of this structure, and it will not be necessary to repeat it here.

V.—SUMMARY.

1. The spermatocytes, as they arise from the diffuse stage succeeding the telophase of the last spermatogonial division, are small cells with very little cytoplasm, the nucleus filling nearly the entire cell body. The chromatin, with the exception of the accessory chromosome, becomes arranged in a spireme, and the proportional amount of cytoplasm is much increased.

2. The spireme breaks down, and a fine, weakly staining reticulum is formed. This becomes finer and less prominent until it is no stronger than the cytoplasmic reticulum. Meanwhile the accessory chromo-

26. Moore, J. E. S., 1895, loc. cit.
27. Paulmier, F. C., 1899, loc. cit.

some has increased enormously in size, much out of proportion to the rest of the nucleus.

3. At this stage the appearance of the nucleus corresponds very closely to that of the germinal vesicle in the egg-cell. The cytoplasm has greatly increased, and large masses of yolk substance have appeared, surrounding the nucleus. On account of these characteristics this stage has been called the pseudo-germinal-vesicle stage.

4. The chromatin appears after the pseudo-germinal-vesicle stage in the form of diffuse masses of chromatin, which quickly take on the cruciform shape characteristic of the typical insect tetrad.

5. At the time of the formation of the tetrads, the accessory chromosome has decreased much in size and its outline has become irregular. Later it again becomes spherical, and at this period is of about the size of a chromosome in the metaphase.

6. Soon after the formation of the tetrads, the centrosome appears in the mass of deutoplasm as a dumb-bell-shaped body. It moves toward the nucleus, separates, astral rays are developed, and the centrosomes move apart upon the membrane. When they have reached points about 100 degrees apart the nuclear membrane disintegrates, and the chromosomes are drawn into the equatorial plate. That part of the membrane over which the centrosomes have not passed disappears first, the rest persisting for some time.

7. The accessory chromosome, freed of its surplus chromatin, can be distinguished up to the disappearance of the nuclear membrane, when it is drawn into the plate with the other chromosomes. It has previously shown no sign of division.

8. The short spindle thus formed lengthens, and the chromosomes are drawn more into the equatorial plate. Astral rays may be distinctly seen connecting the centrosomes and the cell membrane. The centrosomes move apart again to a point a short distance from the cell-wall. The mantle fibers no longer converge toward the centrosomes, but toward the point (the apical point) occupied by them before their last migration. Between the apical points and the centrosomes the mantle fibers are drawn out into parallel threads. At this time the centrosomes have changed their form to that of a cone, with their apices directed toward the point of the spindle.

9. By the contraction of the astral rays the centrosomes are drawn to the cell-wall, where they are flattened out into hemispherical bodies. Synchronously the mantle fibers contract, the chromosomes are separated, and the two daughter groups are drawn toward the poles and take up their final positions at the apical point.

10. The second spermatocytes can be distinguished from the first only by the shape and size of the chromosomes.

11. Soon after the formation of the membrane, after the last ma-

turation division, a portion of the nucleus buds off, and, passing through the cytoplasm, is extruded from the cell. This is the itomere.

12. The protrusion and casting out of the itomere is accompanied and succeeded by the formation of yolk masses and by a great increase in the size of the cell.

13. The pathway left by the itomere, on its passage through the cytoplasm, persists and becomes stronger as the cell advances in development. It marks out the course later taken by the axial filament.

14. The axial filament is not formed by an elongation or outgrowth of the centrosome, but by the condensation of the cytoplasmic reticulum, along the line marked out by the itomere in its passage to the cell wall.

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UNIVERSITY OF KANSAS.



PLATE V.

NOTE.— All drawings were made by the author, with the aid of a camera lucida. A Bausch & Lomb one-twelfth-inch objective and one-inch eyepiece were used. Length of tube, 165 mm.; camera lucida arm., 95 mm.; magnification, about 1000 diameters. Drawings not reduced in reproduction.

FIG. 1. Early spermatocyte, showing small size of cell and relatively large size of nucleus.

FIG. 2. Later stage. The chromatin in the spireme condition. The cell has grown somewhat and the amount of cytoplasm especially has increased. The dark body at one side of the nuclear cavity is the accessory chromosome.

FIG. 3. Considerably later stage. Cell has increased in size. The spireme is broken down and stains diffusely. The accessory chromosome has increased much in size. Yolk masses in a halo around the nucleus.

FIG. 4. The *pseudo-germinal-vesicle stage.* The chromatin, with exception of accessory chromosome, arranged in a diffuse reticulum. The accessory chromosome is at its maximum size and contains practically all the chromatin of the nucleus.

FIG. 5. The chromatin is reappearing in the form of tetrads. The accessory chromosome has decreased much in size. Yolk mass at one side of nucleus.

FIG. 6. Later stage in tetrad formation, showing several modifications of the typical form.

FIG. 7. Later prophase. Tetrads shorter and more massed. Accessory chromosome plainly distinguishable. Centrosome first seen at this stage as a dumb-bell-shaped figure in the mass of dentoplasm.

FIG. 8. The centrosome has moved toward the nucleus. Astral rays have formed.

FIG. 9. The centrosomes have reached the membrane and, having separated, have begun their migration apart.

FIG. 10. Centrosomes still further apart.

FIG. 11. Late prophase. The membrane has partly disappeared and the mantle fibers are seen connecting the centrosomes and chromosomes.

FIG. 12. Stage somewhat earlier than fig. 11.

FIG. 13. Later stage, showing the short spindle. Chromosomes are arranged in the equator. Astral rays are seen extending to the cell membrane.

FIG. 14. The spindle has elongated and the chromosomes show signs of division.

FIG. 15. Slightly later stage.

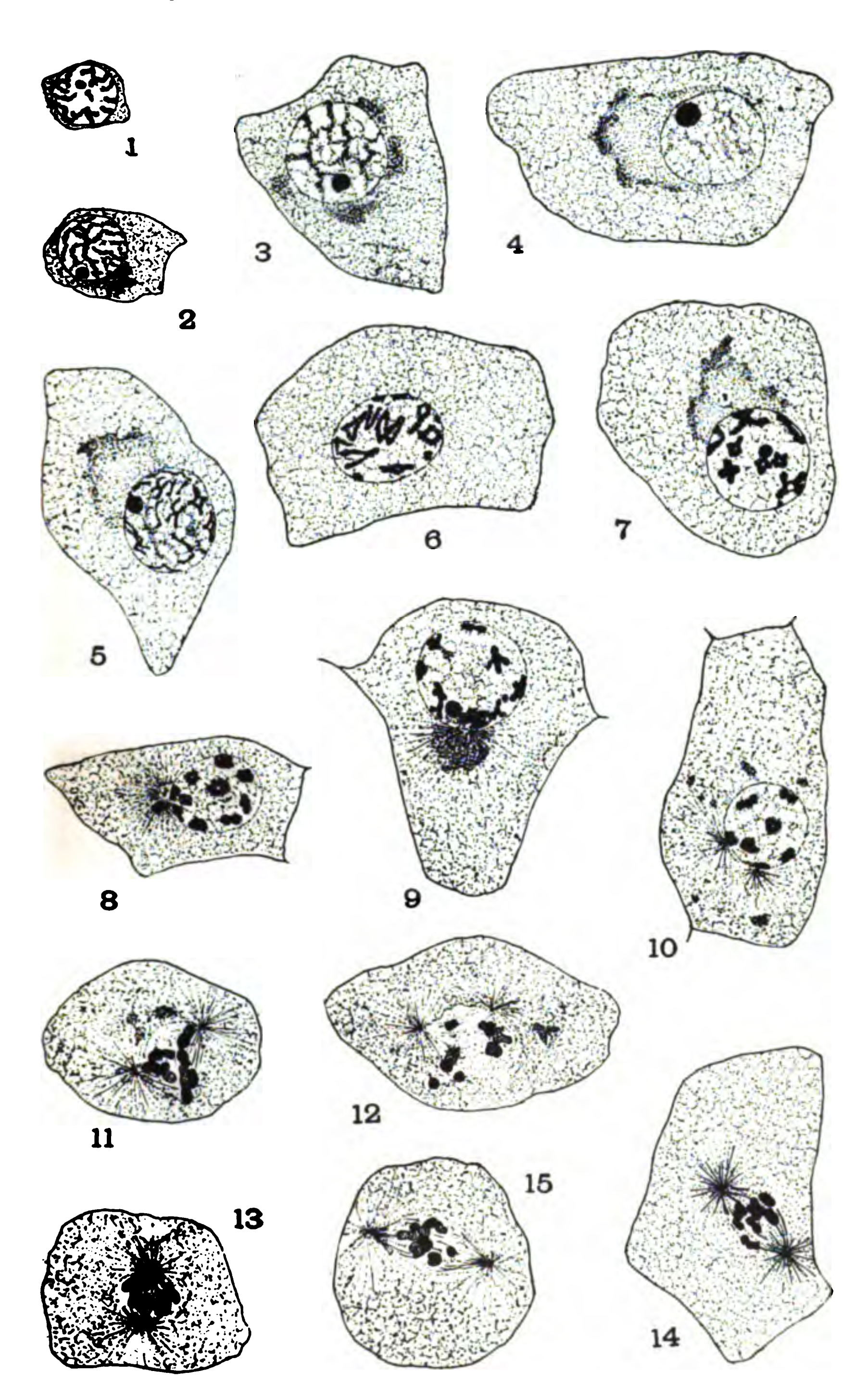

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PLATE VI.

FIG. 16. Later metaphase, showing peculiar character of spindle, with the mantle fibers converging at the *apical point*. Centrosomes are conical in shape. Astral rays connect centrosome and cell membrane.

FIG. 17. Early telophase of first spermatocyte division, showing the position of the daughter groups of chromosomes. The centrosomes are hemispherical in shape and are flattened against the cell membrane.

FIG. 18. Later telophase, showing division membrane. The section is cut in such a plane that the persisting spindle remains do not show.

FIG. 19. Polar view of telophase of first spermatocyte.

FIG. 20. Telophase showing persisting spindle remains. Midbody in the form of a ring.

FIG. 21. Metaphase of second spermatocyte division.

FIG. 22. Telophase of second spermatocyte. The cell-wall shows signs of constriction.

FIG. 23. Later telophase. The chromosomes are distributed throughout the nuclear vesicle. Spindle remains persist. Centrosomes still on the cell membrane.

FIG. 24. Early spermatid.

FIG. 25. Later stage, showing the protuberance upon one side of the nucleus preparatory to the constriction of the *itomere*.

FIG. 26. Later stage in the protrusion of the itomere.

FIG. 27. Still later stage, with the itomere in the cytoplasm midway between the nucleus and the cell-wall.

FIG. 28. Cell, showing the itomere extending from the nucleus to the cell-wall.

FIG. 29. Stage showing the itomere near the cell-wall. The pathway left by it in its passage through the cytoplasm is plainly visible.

FIG. 30. Later stage, showing the itomere extruded from the cell. Its course through the cytoplasm is still to be seen. The nucleus is still open at the place of constriction. The centrosome is seen upon one side of the opening. The cell has increased much in size.

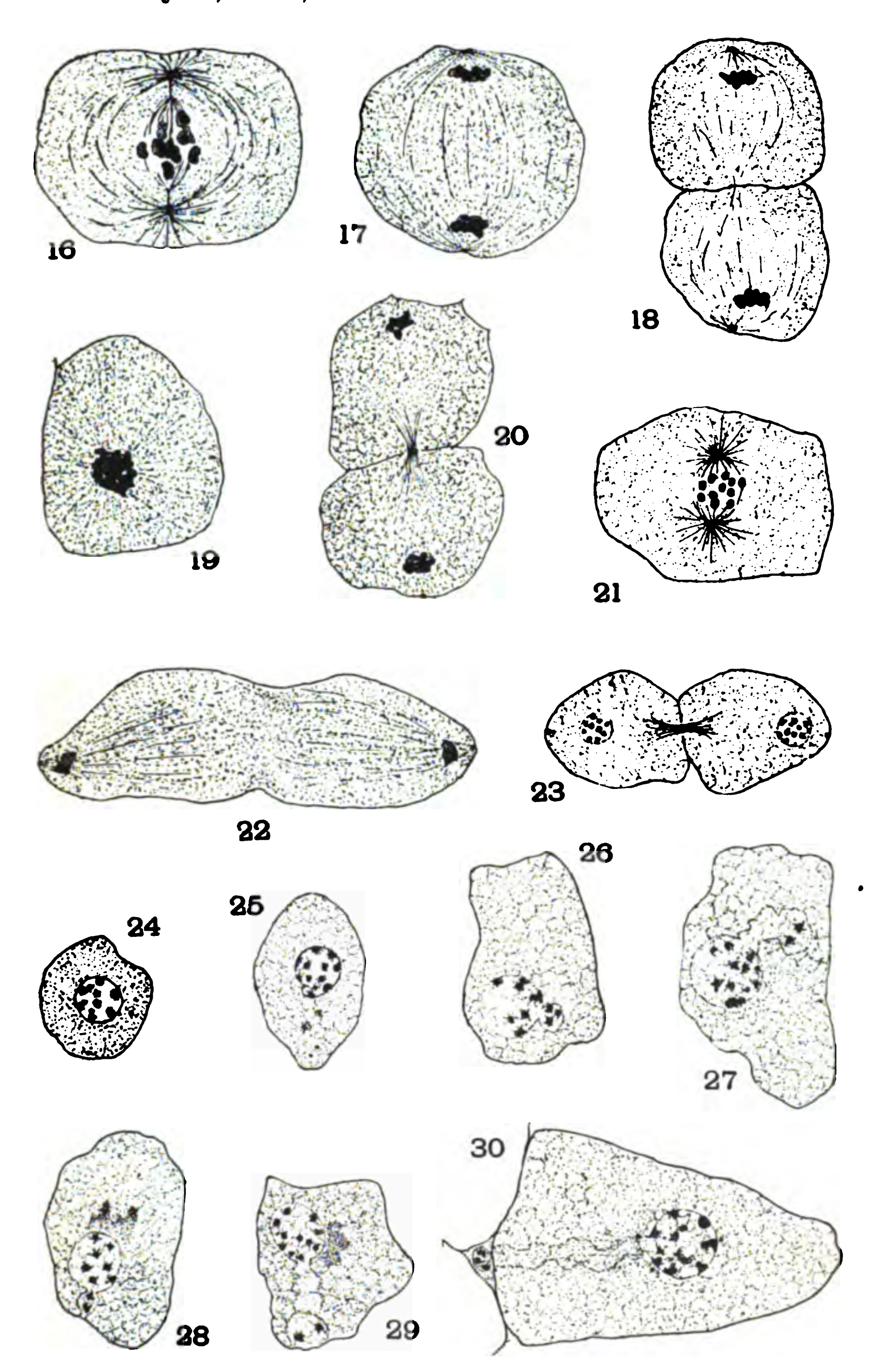

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PLATE VII.

FIG. 31. Considerably later stage. The itomere has disappeared. The cell has grown much in size. The path left by the itomere is more marked than before.

FIG. 32. About the same stage, showing a cross-section of the forming axial filament, with the fibers of the cytoplasmic reticulum radiating from it.

FIG. 33. Later stage. The axial filament more nearly formed. The centrosome has moved nearer its base.

FIG. 34. Later stage in the formation of the axial filament. The cell has begun to elongate. The cytoplasm is broken up into elongated vacuoles extending parallel to the axial filament.

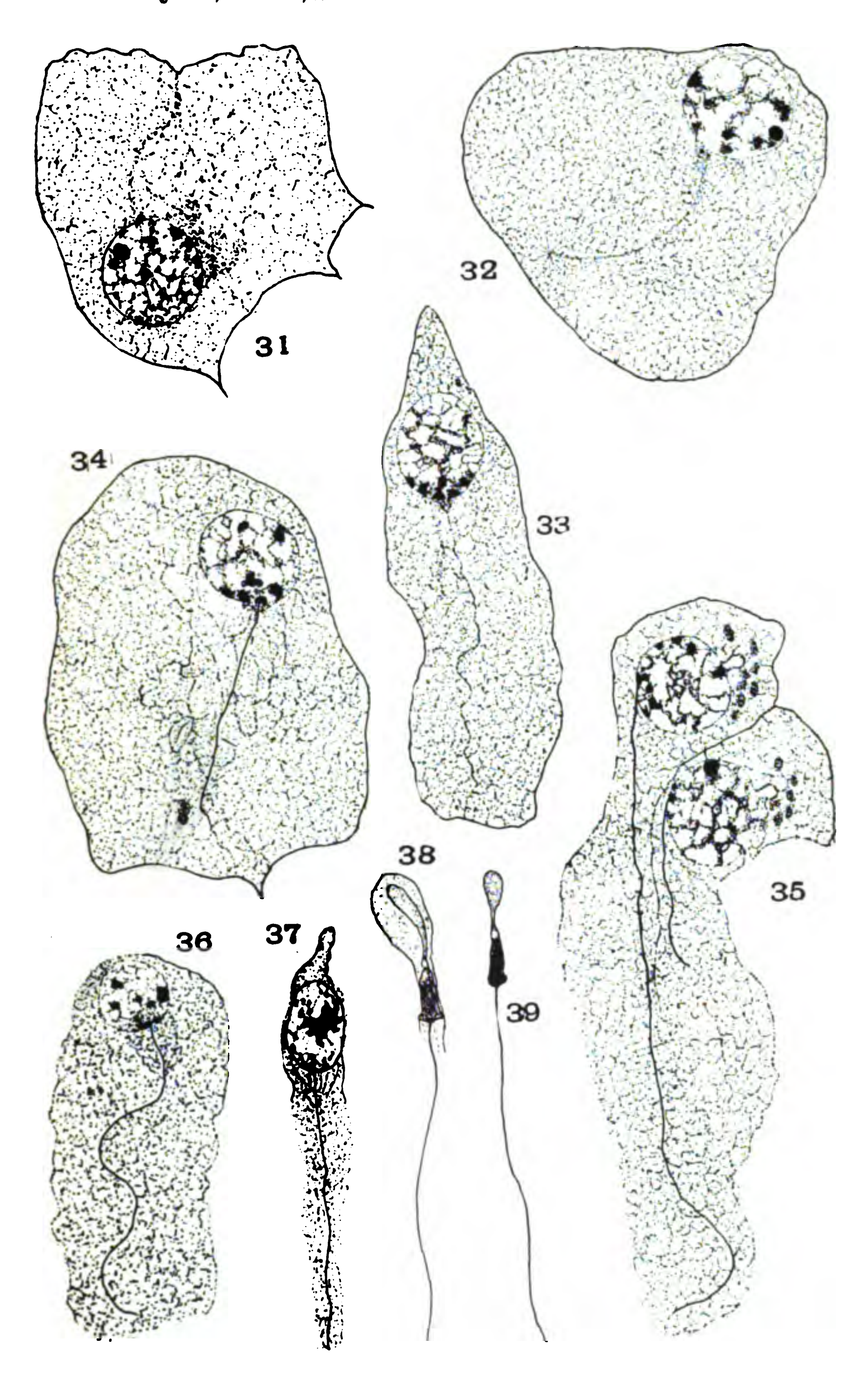
FIG. 35. Much later stage. The cell body has elongated a great deal. The membrane of the posterior part of the cell has disappeared. On the side of the nucleus opposite the insertion of the axial filament there is a large transparent acrosome. At this stage the nucleus has reached its greatest size.

FIG. 36. About the same stage of a smaller cell. Acrosome not shown in the section.

FIG. 37. The nucleus has become condensed and elongated. The acrosome stains more densely. The cytoplasm contains strands of linin extending parallel to the axial filament.

FIG. 38. The nucleus has become still further condensed and has elongated considerably. Acrosome stains darker.

FIG. 39. The nucleus is still more condensed and takes a black stain. Acrosome also stains more strongly.


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ACTION OF LIQUID AMMONIA ON ACID CHLORIDS AND ESTERS.

BY EDWARD BARTOW AND DAVID F. MCFARLAND.

THE product of the action of ammonia gas or an ammonium compound on an ester of an organic acid, or on an acid chlorid, is generally an acid amid. This fact is so well recognized that it is given as a general method for the preparation of acid amids. It is stated thus in Beilstein's Handbuch der Organischen Chemie, volume I, page 1232: "Die Amide entstehen bei der Einwirkung von Ammoniak auf die zusammengesetzten Aether organischer Säuren. Es ist angezeigt, bei möglichst niederer Temperatur zu arbeiten und freie Alkohole fern zu halten (Bonz, Ph. Ch. 2, 900). In der Kälte verläuft die reaction sehr langsam, rascher beim Erhitzen unter Druck. . . . Leichter erhält man die Amide beim Behandeln der Anhydride mit Ammoniak, am bequemsten aber aus den Chloriden und concentrirtem, wässerigem Ammoniak (oder trokenem Ammoniumcarbonat)."

It seems that the ammonia used for these amid syntheses has always been in the form of a gas, or combined in an ammonium compound, and that no one has published results of experiments in which *liquid* anhydrous ammonia was used as the source of the ammonia. The commercial use of liquid ammonia in the manufacture of ice has so cheapened it that it is now an adjunct to every well-equipped chemical laboratory, and it affords a convenient source of ammonia for many experiments. Its comparative purity and freedom from moisture recommend it for some syntheses, and it was particularly on account of these qualities that it seemed possible to use it for the syntheses of acid amids.

A series of experiments was undertaken, therefore, to ascertain, first, whether acid amids could be obtained by the action of liquid ammonia on acid chlorids; second, whether they could be obtained from esters; third, the conditions governing such reactions; and fourth, when amids are not formed, to ascertain what products are formed.

The ammonia used in the following experiments was the commercial product. It was drawn directly from the cylinder into Dewar tubes, or more commonly into flasks, insulated by placing them in beakers and filling the space between the neck of the flask and the sides of the beaker with cotton. This seemed quite effective in preventing too rapid evaporation of the ammonia.

ACTION OF LIQUID AMMONIA ON ACID CHLORIDS.

The chlorids first used were those of mono-, di- and trichloracetic acids. Our experiments were carried on as follows: The chlorid was dropped slowly from a dropping funnel into a small insulated flask containing liquid ammonia. This produced a violent reaction, due not only to reactive tendencies of the two substances, but also to the great difference in their temperatures. The chlorid at the temperature of the room was fully 60° warmer than the boiling ammonia; consequently, dropping the warm chlorid into the cold ammonia caused the latter to boil violently. So violent was the reaction that dense white fumes, probably composed of a mixture of the amid and ammonium chlorid, were given off. This loss was overcome, to a large degree, by cooling the chlorid to the temperature of boiling ammonia, by immersing the vessel containing it in a bath of ammonia, and then dropping ammonia into the cooled chlorid. When the first reaction was over the mixture was treated with an excess of ammonia, which was then allowed to evaporate. The amids were then obtained pure by extracting the white residue with chloroform.

By this method the amids of the three chloracetic acids were obtained. They were identified by their characteristic melting-points, and this identification was supplemented in two of the compounds by chlorine determinations according to the method of Carius.

I. 0.1721 g. substance gave 0.3882 g. AgCl.

Calculated for dichloracetamid, $CHCl_2CONH_2$		Found.
Cl	55.41%	55.76%

II. 0.0731 g. substance gave 0.1952 g. AgCl.

Calculated for trichloracetamid, CCl_3CONH_2		Found.
Cl	65.49%	66.02%

This method, which has proved so successful in preparing chloracetamids, did not, however, succeed with acetamid itself. A similar treatment of acetyl chlorid with liquid ammonia gave a mixture which possessed the unmistakable odor of acetamid; but, thus far, our attempts to obtain *crystals* of acetamid have been unsuccessful.

With bromacetyl chlorid a white mass was obtained, which did not

melt at 200°, but which turned red when heated or allowed to stand for some days. No amid was isolated. The only other chlorids tried in this way were benzoyl chlorid and sulfuryl chlorid. From these benzamid and sulfamid were obtained.

The chief drawback in the above method is the difficulty of freeing the amid from the ammonium chlorid which is formed at the same time. Up to this time we have been prevented from further experiments with chlorids by our lack of pure specimens. When such specimens are secured, the experiments will be continued.

ACTION OF LIQUID AMMONIA ON ESTERS.

Since the action of aqueous and alcoholic ammonia on esters of organic acids will cause the formation of amids, sometimes even in the cold, a series of experiments with liquid ammonia and the esters promised good results. The expected reaction is as follows:

$$RCOOC_2H_5 + NH_3 = RCONH_2 + C_2H_5OH$$

for the ethyl esters, and, more general,

$$RCOOR' + NH_3 = RCONH_2 + R'OH.$$

Authorities differ as to the effect of alcohol on amid synthesis. One (Bonz, Ph. Ch. 2, 900) says free alcohol must not be present. Another uses alcoholic ammonia in the synthesis. It would seem to us that no general statement should be made, since, in some of our experiments, we easily obtained well-crystallized products, while in others no crystals were obtained; possibly because of the alcohol formed by the reaction.

The method of procedure was similar to that used with chlorids. The ester was dropped into the liquid ammonia contained in a small crystallizing dish insulated by cotton. A large excess of ammonia was used—from six to ten times the bulk of the esters. The dish was covered with a ground-glass plate and allowed to stand until the ammonia was all evaporated. When a crystalline residue was obtained, it was dried on a porous plate and a melting-point determination made. The reaction between the esters and the ammonia is not violent, as when chlorids are used, so that when crystals can be obtained the method is much better than the chlorid method.

Forty-two esters have been treated in this way. From nine of them, crystallized compounds were obtained which had melting-points corresponding to the melting-points given for the respective amids in the literature on the subject. Two gave compounds with higher melting-points, and seven gave products, with high melting-points, that were probably decomposition products. The remainder were apparently not acted upon.

The first esters tried were those of the chloracetic acids. These

gave such good results that, by analogy, it might have been expected that the method would be general in its application. The yield of amid in each case was quantitative; and they were, moreover, pure and well crystallized, yet, with the exception of cyanacetic ethyl ester, no others have given as good results.

The reaction, too, was much less violent than the one accompanying the formation of the amids from the chlorids. The esters and the ammonia mix with little rise in the temperature of the ammonia.

Cyanacetic ethyl ester gave a well-crystallized body which melted at 118°, agreeing with the melting-point of the substance given by Henry (Bl. 48, 656), but differing from that assigned by Hoff 105° (J. 1864, 561).

The ethyl esters of the fatty acids were tried, as follows: Formic, acetic, propionic, butyric, valeric, caprylic, and pelargonic. None of these yielded amids except pelargonic acid ethyl ester, which gave crystals mixed largely with the unchanged ester. When these crystals were freed from the ester, they gave a melting-point of 99°, agreeing with that given by Hofmann (B. 15, 984).

From the results above described, it seemed probable that the substitution of one or more hydrogen atoms in the alkyl radical of the acid by the halogen had some influence upon the readiness with which an amid could be formed. To test this hypothesis, the action of ammonia on the esters of a number of substituted fatty acids was investigated, with the result that we have thus far obtained amids from only two of them, dibromacetic ethyl ester and chlorpropionic ethyl ester. Substances were obtained from these whose melting-points correspond to those recorded in chemical literature. From some of the others crystalline products were obtained, but the melting-points varied from those recorded for the expected amids. For instance, from the bromacetic ethyl ester a mass of white cubical crystals was formed, which did not melt below 200°, which sublimed at high temperatures, and which turned red on being heated or after standing a a few days. This substance seems to be a mixture of ammonium bromid and some other compound, which we have not yet separated and identified, but which is possibly glycinamid or amidoacetamid. From tribromacetic acid ethyl ester white crystals were obtained which melted at 45° instead of 120°, the temperature at which tribromacetamid should melt (Brezina, J. 1881, 673). The composition of this substance has not yet been determined. Bromin substitution products of esters of some of the higher fatty acids give solid residues resembling that obtained from bromacetic acid ester and probably consisting of ammonium bromid and decomposition products.

The only chlorin substitution product besides the chloracetic

ethyl esters which was available was chlorpropionic ethyl ester. Thus far the only product obtained from this ester has shown a melting-point of 72°, which is lower than that assigned to chlorpropionamid, (80°), by Beckurts-Otto (B. 9, 1592).

From the foregoing, it appears that the presence of chlorin or cyanogen in the alkyl radical aids in the formation of amids, while the weaker halogen bromin generally causes the compound to break up with the formation of ammonium bromid and decomposition products. We have tried, also, the action of a few esters in which the hydrogen of the alkyl is substituted by an organic radical. These radicals do not seem to aid in amid formation. From phenylacetic ethyl ester we have obtained no results. From benzoylacetic ethyl ester a small amount of a substance was obtained, which melted at 167°. This substance is apparently not identical with the benzoylacetamid of Obriga (A. 266, 232), which melted at 113°.

Acetacetic acid ethyl ester gave a white crystalline substance, which, as the temperature rose to that of the room, quickly liquified, forming a yellow oil. This is undoubtedly the same substance mentioned by Collie (A. 226, 298), who says that at 0° acetacetic acid ethyl ester absorbs dry ammonia gas directly, forming an unstable addition product, $C_6H_{10}O_3NH_3$, which quickly goes over into amidocrotonic acid ethyl ester, $C_6H_{11}NO_2$.

From the esters of dibasic acids, there were available those of oxalic, malonic, succinic and tartaric acids. Two of these only, oxalic and tartaric, gave amids by the above method. The oxamid formed very readily as a white, crystalline powder. It did not melt when heated to 200°, but sublimed at higher temperatures. From tartaric acid ethyl ester, after two treatments with ammonia, a small quantity of a substance, melting at 166°, was obtained. We can find no authority for a melting-point of tartramid.

The action of ammonia on the ethyl esters of lactic, lævulinic and citric acids was also investigated. None of these seemed to be changed by the treatment, except that the citric acid ester became slightly blackened.

Four esters of aromatic acids were tried, ethyl benzoate, methyl benzoate, ethyl phthalate, and ethyl salicylate. Of these the phthalic ester gave a white crystalline compound, which melted at 175°. The melting-point of phthalamid, according to Bülow (A. 236, 188), is 219°.

Four other esters have been treated in this manner. Two of them, orthoformic acid ethyl ester and ethyl carbonate, showed no change, but with ethyl chlorcarbonate a vigorous reaction took place; dense white fumes were formed, and a considerable quantity of an amorphous white substance was left in the vessel. This did not melt

when heated to 200° but was partly soluble. We have not yet determined whether the substance is ammonium chlorid or whether some of the possible substances have been formed.

ACTION OF ESTERS AT HIGHER TEMPERATURES.

Our failure to obtain some amids by the above method might be due to the low temperature at which the reaction must take place, when the ammonia is boiling under ordinary pressure. Therefore, we attempted to get a more rapid and more complete reaction by heating the mixture of the ester and anhydrous ammonia. The esters were each sealed, with about four times their bulk of liquid ammonia, in strong glass tubes. In one series of experiments these were allowed to warm to the temperature of the room, and in a second series they were heated to 60° or 70°. The tubes were kept sealed for at least twelve hours. They were then cooled with boiling ammonia, opened, the ammonia evaporated off, and the residue examined.

Eight esters, selected as being types of various acids, were treated in this way. Of these, acetic acid ethyl ester gave no definite results. Acetacetic acid ethyl ester formed a mass of crystals which remained for some time after the ammonia was evaporated, but which soon liquified on exposure to the air, forming an oily yellow liquid. We have not yet obtained a satisfactory melting-point for these crystals. Some of the crystals were at once sealed in a glass tube, and have been preserved in this way for more than a year.

Malonic acid ethyl ester formed white crystals of malonamid, identified as such by the melting-point, 170° (Hoff, J. 1875, 528).

Pelargonic acid ethyl ester formed a soapy mass when treated in this way. From this mass, crystals of pelargonic amid were obtained. The result agrees with that from ammonia at its boiling-point under ordinary pressure.

Succinic ethyl ester, benzoic ethyl ester, benzoylacetic ethyl ester and ethyl carbonate gave no results.

In the second series of experiments, in which the tube containing the ester and ammonia was heated to 60° or 70° in a water-bath, six esters were used. Acetic ester gave a product which had the characteristic odor of impure acetamid, but we have not yet succeeded in isolating the pure substance. Tartaric acid ester formed the same white crystalline substance that was formed in the cold.

From benzoic ethyl ester, succinic ethyl ester, valeric ethyl ester and benzoylacetic ethyl ester no results were obtained.

With only one of the esters tried—malonic acid ethyl ester—have we had better results at higher temperatures than with the mixture of ester and ammonia at the boiling-point of the liquid ammonia.

CONCLUSION.

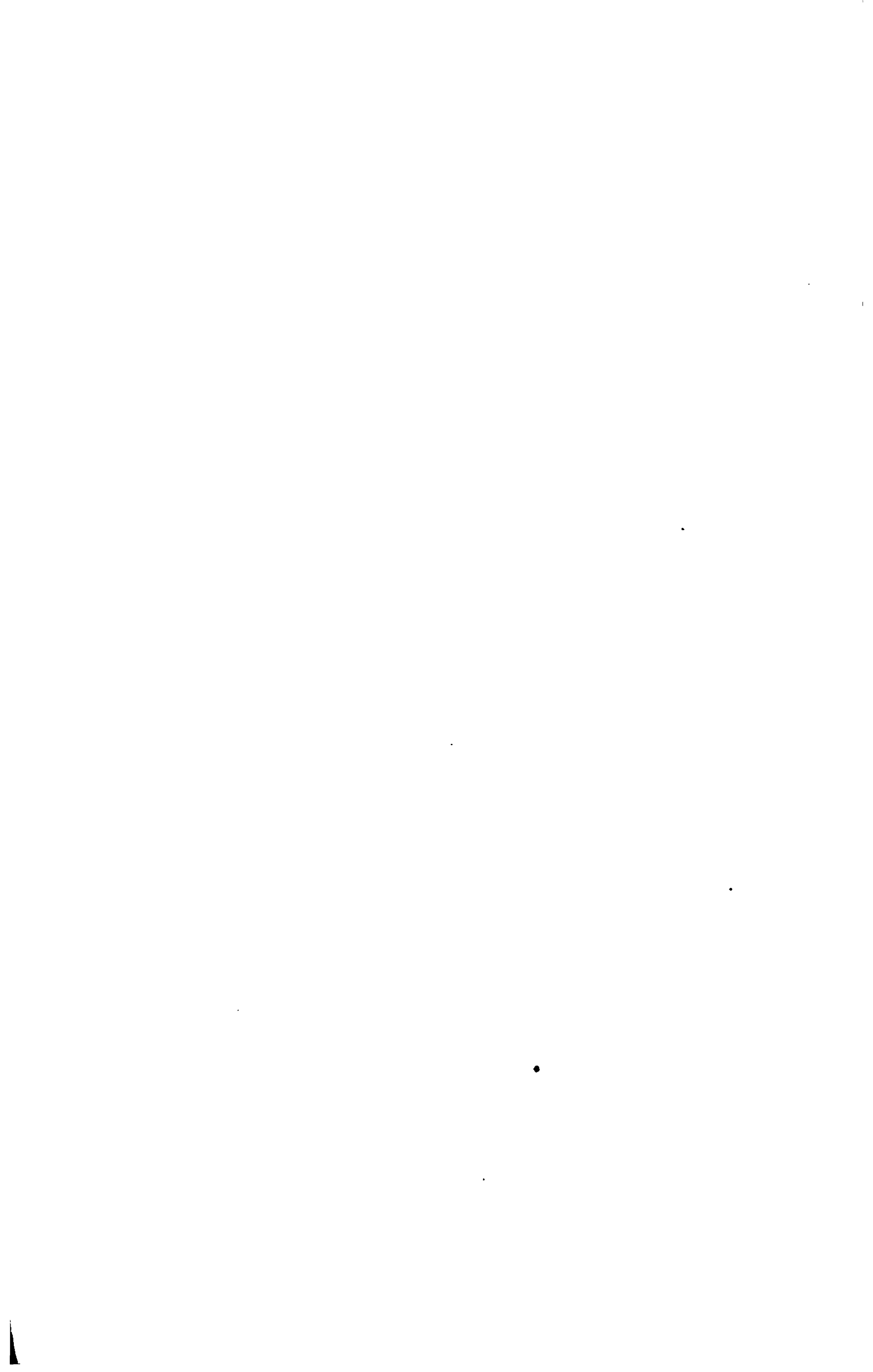
The few acid chlorids tried, except bromacetylchlorid, gave amids. In our experiments with chlorids and liquid ammonia, we have prepared the amids of the three chloracetic acids and benzamid. Mr. O. F. Stafford has prepared sulfamid.

A few esters. especially the chloracetic ethyl esters, gave better results in forming amids, and the operation was more easily carried out than with the corresponding chlorids. We have, by the addition of esters to liquid ammonia, prepared the amids of the three chloracetic acids, of dibromacetic acid, cyanacetic acid, chlorpropionic acid, pelargonic acid, oxalic acid, and tartaric acid. Malonic acid amid was formed only at a higher temperature.

A few esters gave substances whose melting-points varied from those of expected amids found recorded in chemical literature.

Many of the esters tried have given no well-crystallized amids under the conditions which prevailed in these experiments. The causes for this may be conjectured: First, the low temperature of the reaction, as shown in the case of malonamid, which was not formed at the temperature of boiling ammonia, but which form in a sealed tube at the temperature of the room; second, the short time for the reaction allowed by the evaporation of ammonia from open vessels; third, the reaction of ammonia on esters is reversible, and is even prevented by excess of alcohol (Bonz, Ph. Ch. 8, 900).

We hope to carry our experiments farther, to identify the rest of the substances obtained, and to study the action of liquid ammonia on the esters at higher temperatures and in the presence of diluting media, such as ether and benzene.



A NEW THEORY OF COLLINEATIONS IN SPACE, II.

BY H. B. NEWSON.

NOTE.—In this journal, Series A, Vol. VI, pp. 63-69, and Vol. IX, pp. 65-71, the writer has enumerated, discussed and constructed the thirteen types of collineations in space; also in volume X, No. 2, the properties of the fundamental group, G_3(ABCD) of type I were discussed. In the present paper the same thing is done for types II, III, and IV. In future papers the remaining types of collineations in space will be treated in the same manner. This series of papers will then be extended to include the synthetic determination and discussion of all real continuous groups of collineations in space and their classification according to the thirteen types.

A knowledge of the corresponding theory in one and two dimensions is assumed on the part of the reader. A memoir on "A New Theory of Collineations in the Plane," though written earlier than the papers of this series, will appear some months hence in the *American Journal of Mathematics*. The memoir treats of all real and imaginary collineations in the plane.

The projected papers, of which the present is the second, are designed to develop completely my theory of real collineations in space. The extension of the theory to include all real and imaginary collineations is so easy that it will readily be made by most readers. The papers will be published in this journal as rapidly as possible.—H. B. N.

A.—*On the Group of Collineations G_3(ABCl) of Type II and its Subgroups.*

THE real collineations in space of type II show two subtypes, viz., hyberbolic and elliptic. In the first subtype the invariant figure is real in all of its parts; in the second subtype the points B and C are conjugate imaginary, and hence the lines AB and AC and the planes ABl and ACl are also conjugate imaginary. These two cases must be treated separately.

§1. THE GROUP hG_3(ABCl) AND ITS ONE-PARAMETER SUBGROUPS.

The group $hG_3(ABCl)$.—A collineation T of type II is completely determined by the position of its invariant figure (ABCl) and three parameters k, k′ and t. k is the constant cross-ratio along AB, k′ that along AC, and t is the parabolic constant of the transformation along AC. In the hyperbolic case these three parameters are all real and independent of one another, and hence there are ∞^3 collineations, leaving the figure h(ABCl) invariant; they form a three-parameter group hG_3(ABCl).

THEOREM 1. The aggregate of all collineations of type II having the same invariant figure h(ABCl) forms a three-parameter group hG_3(ABCl).

One-parameter subgroups of $hG_3(ABCl)$.—The group hG_3(ABCl) contains ∞^2 one-parameter subgroups, as we shall now show. Let us

put $k'=k^{1-r}$, and $k=a^t$; *i. e.*, $k=a^t$ and $k'=a^{(1-r)t}$, where a and r are two real constants. We consider now the system of collineations in $hG_3(ABCl)$ whose parameters satisfy these relations.

Let T and T_1 be two collineations whose parameters are a^t, $a^{(1-r)t}$, t, and a^{t_1}, $a^{(1-r)t_1}$, t_1, respectively. Their resultant, T_2, has the parameters a^{t_2}, $a^{(1-r)t_2}$, t_2 where $t_2=t+t_1$. Since there is only one variable parameter, t, this system contains ∞^1 collineations; these form a one-parameter group, since the resultant of any two collineations of the system is again a collineation of the system. Such a one-parameter group is designated by $hG_1(ABCl)_{ar}$.

There is a one-parameter group within $hG_3(ABCl)$ for each real value of r and each positive value of a; hence $hG_3(ABCl)$ contains ∞^2 one-parameter subgroups. The properties of one of these subgroups are the same as the properties of a one-dimensional parabolic group.

THEOREM 2. The group $hG_3(ABCl)$ contains ∞^2 one-parameter subgroups; for each of these subgroups a and r have fixed values, and t is the variable parameter.

Invariant curves and surfaces of $hG_3(ABCl)_{ar}$.—The one-parameter group $hG_1(ABCl)$ leaves invariant, besides the fundamental figure h(ABCl) a system of ∞^2 path curves and certain systems of surfaces passing through these path curves. We find the equations of these invariant surfaces as follows:

Let (ABCD), where D is some point on l, be the tetrahedron of reference, and let T be a collineation of the group $hG_1(ABCl)$ which transforms a point P whose coordinates are (x, y, z, w) to P_1 whose coordinates are (x_1, y_1, z_1, w_1). Pass planes through PAC and P_1AC. Writing out the cross-ratio of the four planes through AC we have

$$\frac{x_1}{z_1} : \frac{x}{z} = a^t, \tag{1}$$

since this cross-ratio is the same as that along the line AB. In like manner we derive the equations

$$\frac{y_1}{z_1} : \frac{y}{z} = a^{(1-r)t}, \tag{2}$$

$$\frac{y_1}{x_1} : \frac{y}{x} = a^{-rt}, \tag{3}$$

$$\frac{w_1}{z_1} - \frac{w}{z} = t. \tag{4}$$

Suppose that P is a movable point and P_1 fixed, so that any function of the coordinates of P_1 only is a constant. Eliminating t from (1) and (4) we get

$$za^{\frac{w}{z}} = Cx, \qquad \text{I}$$

which is the equation of a family of invariant cones with vertices at

C. In like manner eliminating t from (2) and (4), (1) and (2), and (3) and (4) we have, respectively,

$$za^{\frac{(1-r)w}{z}}=Cy, \qquad \text{II}$$

$$x^{r-1}\, y=Cz^r, \qquad \text{III}$$

$$ya^{\frac{rw}{z}}=Cx. \qquad \text{IV}$$

Equations I, II, III give families of invariant cones whose vertices are respectively at C, B, and A. Equation IV represents an invariant family of ruled surfaces not conical.

We have thus found four families of ruled surfaces which are invariant under all the collineations of the group $hG_1(ABCl)$. The path curves of the group are the ∞^2 common intersections of these families of surfaces.

THEOREM 3. There are four distinct families of ruled surfaces invariant under all the collineations of the group $hG_1(ABCl)$; three of these are families of cones. The ∞^2 curves of intersection of these invariant surfaces are the path curves of the group.

§ 2. TWO-PARAMETER SUBGROUPS OF $hG_3(ABCl)$.

Two-parameter groups leaving invariant a family of surfaces.— If r remains constant while a assumes in turn all real values between 0 and ∞, and we have ∞^2 one-parameter groups, all of whose transformations leave invariant the family of cones given by equation III, for the equation of this family of cones is independent of a. The path curves of the ∞^1 one-parameter groups all lie on these cones. This system of ∞^2 collineations forms a two-parameter group $hG_2(ABCl)_r$; the parameters of this group are a and t. The group $hG_3(ABCl)$ contains ∞^1 two-parameter subgroups, one for each real value of r.

In like manner if a is constant and r varies, we get a two-parameter group, leaving invariant the family of cones given by equation I. Again, if a and r vary in such a manner that $a^{(1-r)}$ is a constant, we get a two-parameter group leaving invariant the family of cones given by equation II. Finally, if a and r vary so that a^r is constant, we have a two-parameter group whose invariant family of surfaces is given by equation IV.

Thus we see that the group $hG_3(ABCl)$ contains four singly infinite systems of two-parameter subgroups; three of these systems leave invariant families of cones, and one system leaves invariant a family of ruled surfaces.

THEOREM 4. The three-parameter group $hG_3(ABCl)$ contains four singly infinite systems of two-parameter subgroups; these are given by $r=$const.; $a=$const.; $a^{1-r}=$const., and $a^r=$const.

§ 3. Some Properties of the Subgroups of $hG_3(ABCl)$.

Negative values of k and k'.—The three parameters of $hG_3(ABCl)$, viz., k, k', t, are all real and each may assume in turn all real values, both positive and negative. Let t, k and k' be taken to be the rectangular coordinates, x, y, z, respectively, of a point in a space S. Evidently there is a collineation in $hG_3(ABCl)$ corresponding to each point in S. The one- and two-parameter groups in $hG_3(ABCl)$ are represented by curves and surfaces in S. The system of curves given by the equations

$$y=a^x \text{ and } z=a^{(1-r)x}, \qquad \text{V}$$

in which a and r are parameters, represents the system of one-parameter subgroups of $hG_3(ABCl)$.

In order that the curves given by equations V shall be continuous curves the value of a must be positive. The curve lies always on the positive side of the plane $y=0$ and on the positive side of $z=0$; hence it is confined to the first and second octants. The curves of the family $y=a^x$ and $z=a^{(1-r)x}$ contain every point in the first and second octants but no points in the other six octants. Consequently the group $hG_3(ABCl)$ contains transformations which are not included in any of its subgroups. In fact, only one-third of all the transformations in $hG_3(ABCl)$ are to be found in its subgroups; the transformations for which k and k' are negative cannot be generated from infinitesimal collineations in group $hG_3(ABCl)$.

The curves all pass through the point (0, 1, 1). This point corresponds to the identical transformation which belongs therefore to every one-parameter subgroup of $hG_3(ABCl)$. Every curve of the system is asymptotic to the axis of x, to the right or to the left according as we have $a<1$ or $a>1$.

Theorem 5. Only one-third of the collineations in the group $hG_3(ABCl)$ belong to its one-parameter subgroups and are generated from infinitestimal collineations in $hG_3(ABCl)$.

§ 4. Some Special Subgroups of $hG_3(ABCl)$.

Two-parameter subgroups of types VIII, IX, and XI.—The parameters k, k' and t in $hG_3(ABCl)$ may have such values that the transformation along one or more of the invariant lines of the figure (ABCl) is identical, so that every point on such a line is an invariant point. In such cases the collineations are of another type than II.

If $t=0$ and k and k' vary independently, the one-dimensional transformation along Al is identical, and we have a two-parameter subgroup of type VIII in $hG_3(ABCl)$. If $k'=k$, the one-dimensional transformation along BC is identical, and there results a two-parameter subgroup of type IX in $hG_3(ABCl)$. If $k=1$ or $k'=1$, the

one-dimensional transformations along AB and AC, respectively, are identical, and there results in each case a two-parameter subgroup of type XI in $hG_3(ABCl)$.

In terms of the parameters a, r and t the subgroup of type VIII results when $a=\infty$; the subgroup of type IX results when $r=0$; the two subgroups of type IX result when $r=1$ and ∞ respectively.

THEOREM 6. The group $hG_3(ABCl)$ contains one two-parameter subgroup of type VIII, one of type IX, and two of type XI.

Subgroups of types VI, VII and X in $hG_3(ABCl)$.—If $t=0$ and $k=1$, the transformation in the plane ABl is identical and leaves invariant all points in the plane. The corresponding collineations in space are of type VI,* C being the vertex and ABl the axial plane. The remaining parameter k' gives us a one-parameter subgroup of type VI in $hG_3(ABCl)$. In like manner, if $t=0$ and $k'=1$, we have a one-parameter subgroup of type VI whose vertex is B and whose axial plane is ACl.

If $k=1$ and $k'=1$, the collineation in the plane ABC is identical, the parameter t gives us a one-parameter subgroup of type VII in $hG_3(ABCl)$; A being the vertex and ABC the axial plane.

If $t=0$ and $k'=k$, the one-dimensional transformations along AC and BC are both identical; there results a one-parameter subgroup of type X in $hG_3(ABCl)$.

In terms of a, r and t the subgroup of type VII is given by $a=1$; the two subgroups of type VI are given by $t=0$ and $r=1$, $t=0$ and $r=\infty$, respectively; the subgroup of type X is given by $t=0$ and $r=0$.

THEOREM 7. The group $hG_3(ABCl)$ contains one one-parameter subgroup of type VII, two of type VI, and one of type X.

Other special subgroups of $hG_3(ABCl)$.—There are only three other special subgroups of $hG_3(ABCl)$ to be noticed; these are when the path curves in the plane ABC are conics. These path curves are conics for three values of r, viz., $r=-1, 2, 1/2$. When $r=2$ the conics have double contact at B and C; when $r=-1$ or $1/2$ the conics have double contact at A and C, A and B, respectively. These are two-parameter subgroups of $hG_3(ABCl)$.

§ 5. THE ELLIPTIC CASE $eG_3(ABCl)$.

Parameters of $eG_3(ABCl)$.—In the elliptic subtype of type II, where the points B and C are conjugate imaginary, the theory is somewhat different from that of the hyperbolic subtype. In the plane ABC the two-dimensional collineations of the elliptic subtype and the parameters are given in the form $k=\exp.(c+i)\theta$; thus c and θ are the parameters. The three parameters of eG_3 are there-

fore c, θ, and t. It is convenient to replace θ by nt and thus have c, n, t as the three parameters.

Let T and T_1 be any two collineations of the group $eG_3(ABCl)$ for which the parameters are c, n, t and c_1, n_1, t_1, respectively. Let the values of the parameters of the resultant be c_2, n_2, t_2. We have, therefore, $t_2 = t + t_1$, $n_2t_2 = nt + n_1t_1$, and $c_2n_2t_2 = cnt + c_1n_1t_1$.

One- and two-parameter subgroups of $eG_3(ABCl)$.—If c and n remain constant and only t varies, we get a one-parameter subgroup of eG_3. If c is fixed and n and t vary, or n fixed and c and t vary, there result two-parameter subgroups. Thus we have two distinct singly infinite systems of two-parameter subgroups and ∞^2 one-parameter subgroup of $eG_3(ABCl)$. The path curves of the one-parameter subgroup are, except in very special cases, transcendental curves; in these special cases the subgroups are of other types than type II.

Special subgroups of $eG_3(ABCl)$.—If $t=0$ and c and θ vary, the transformation along the line Al is identical and there remains a two-parameter elliptic subgroup of type VIII. When $c=\infty$, $n=0$, $cn \pm 0$, the transformation along BC is identical, and there results a two-parameter subgroup of type IX. When $c=\infty$, $n=0$, and $cn=0$, the transformation in the plane ABC is identical, and there results a one-parameter subgroup of type VII. When $t=0$, $c=\infty$, $n=0$, and $cn=0$, *i. e.*, when the conditions for a two-parameter group of type VIII and type IX are simultaneously fulfilled, the transformations along both Al and BC are identical, and there results a one-parameter subgroup of type X. The elliptic group $eG_3(ABCl)$ has no real subgroups of types VI or XI.

THEOREM 8. The group $eG_3(ABCl)$ contains one two-parameter group of type VIII and one of type IX; also one one-parameter subgroup of type VII and one of type X.

The group $eG_3(ABCl)$ contains one other two-parameter subgroup worthy of special notice. When $c=0$ the path curves of the one-parameter group of collineations in the plane ABC are conics having double contact at B and C. This group derives its importance from the fact that, in case the plane ABC is at infinity and the points B and C are the circular points in the plane, it becomes the group of all screw motions about the line l as an axis.

B.—*On the Group of Collineations $G_3(ABll')$ of Type III and its Subgroups.*

§1. The Group $G_3(ABll')$ and its One-parameter Subgroup.

The group $G_3(ABll')$.—A real collineation in space of type III leaves invariant a figure $(ABll')$ real in all of its parts, consisting of two points A and B and their join; two lines l and l', the first through A and the second through B; and hence also the two planes ABl and ABl'. The one-dimensional transformations along l and l' are both parabolic; that along AB hyperbolic. The plane collineations in the invariant planes ABl and ABl' are both of type II.

A collineation T of type III is completely determined by the position of its invariant figure $(ABll')$ and three parameters k, t, t'; k is the constant cross-ratio along AB, t is the parabolic parameter along Al, and t' that along Bl'. These three parameters are all real and vary independently; hence there are ∞^3 collineations of type III, leaving the fundamental figure $(ABll')$ invariant; these form a three-parameter group $G_3(ABll')$.

THEOREM 9. The aggregate of all collineations of type III in space having the same invariant figure $(ABl'l)$ forms a three-parameter group $G_3(ABll')$.

One-parameter subgroups of $G_3(ABll')$.—It will now be shown that the group $G_3(ABll')$ contains ∞^2 one-parameter subgroups. Let $k=a^t$ and $t'=nt$, where a and n are constants; a is necessarily positive. By imposing these conditions on the parameters k and t', we select from $G_3(ABll')$ a system of ∞^1 collineations. The properties of this system are now to be examined.

Let T and T_1 be two collineations whose parameters are respectively a^t, nt, t, and a^{t_1}, nt_1, t_1. Their resultant, T_2, has the parameters a^{t_2}, n_2t_2, t_2. For along Al we have $t_2=t+t_1$; along Bl' we have $n_2t_2=nt+n_1t_1$; along AB we have $k_2=kk_1=a^t$. $a^{t_1}=a^{t+t_1}$. Hence the system of ∞^1 collineations, whose parameters are a^t, nt, t, forms a one-parameter continuous group whose parameter is t. This group is designated by $G_1(ABll')_{an}$.

There is a one parameter subgroup within $G_3(ABll')$ for each value of n and each positive value of a; hence $G_3(ABll')$ contains ∞^2 one-parameter subgroups. The properties of one of these subgroups are the same as the properties of a one-dimensional parabolic group.

THEOREM 10. The group $G_3(ABll')$ contains ∞^2 one-parameter subgroups; for each of these subgroups a and n have fixed values and t is the variable parameter.

Invariant curves and surfaces of $G_1(ABll')$.—We shall now determine the systems of invariant surfaces of the one-parameter group $G_1(ABll')$, whose intersections are the ∞^2 path curves of the group. Let (ABCD), where C is some point on l' and D some point on l, be the tetrahedron of reference; and let T be a collineation of the group $G_1(ABll')$ which transforms a point P, whose coordinates are (x, y, z, w) to P_1 whose coordinates are (x_1, y_1, z_1, w_1). Pass planes through PAl, P_1Al, PAl', P_1Al', PAB, and P_1AB. We obtain at once the following equations:

$$\frac{x_1}{y_1} - \frac{x}{y} = t' = nt, \qquad (1)$$

$$\frac{w_1}{z_1} - \frac{w}{z} = t, \qquad (2)$$

$$\frac{y_1}{z_1} : \frac{y}{z} = a^t. \qquad (3)$$

By eliminating t from these equations of transformation we obtain the following equations of invariant surfaces of $G_1(ABll')$:

$$y = Ca^{\frac{w}{z}}z, \qquad \text{I}$$

$$y = Ca^{\frac{t}{nz}}z, \qquad \text{II}$$

$$(x-cy)z = nwy. \qquad \text{III}$$

Equations I and II represent families of transcendental ruled surfaces while equation III always represents a family of quadric surfaces. The intersections of these three systems of surfaces are the path curves of the group $G_1(ABll')$.

THEOREM 11. There are three distinct families of ruled surfaces invariant under all the collineations of the group $G_1(ABll')$; two of these families are transcendental surfaces and one is a family of quadrics. These surfaces intersect in the path curves of the group.

§ 2. TWO-PARAMETER SUBGROUPS OF $G_3(ABll')$.

Subgroups with transcendental invariant surfaces.—Let a, n and t be the three parameters of $G_3(ABll')$. If a remains constant while n and t vary, we have a one-parameter subgroup all of whose transformations leave invariant the family of transcendental surfaces given by equation I. These form a two-parameter group, and there is one such group for each positive value of a.

If a and n vary in such a manner that a^n remains constant and t varies independently, we get a two-parameter subgroup of $G_3(ABll')$, leaving invariant the family of surfaces given by equation II. There is one such subgroup for each value of the constant a^n.

Subgroups with invariant quadric surfaces.—If n remains constant and k and t vary independently, we have a two-parameter sub-

group, leaving invariant the family of quadric surfaces given by equation III. There is one such subgroup for each value of n.

The lines l and l′ are two generators of the same system and AB a generator of the other system on every invariant quadric. These invariant quadrics always have both systems of generators real.

THEOREM 12. The three-parameter group G_3(ABll′) contains three singly infinite systems of two-parameter subgroups. These are given by a=const.; a^n=const.; and n=const. Every collineation of type III leaves invariant a family of quadric surfaces.

§ 3. SOME PROPERTIES OF THE SUBGROUP OF G_3(ABll′).

Graphic representation of subgroups of G_3(ABll′).—The three parameters t, t′, k of G_3(ABll′) are all real and may be taken as the coordinates x, y, z, respectively, of a point in a space S. There is a collineation of the group for each real point in S. The one- and two-parameter subgroups of G_3(ABll′) are represented by curves and surfaces respectively in S.

The surfaces given by the equations

$$z=a^x \text{ and } y=nx$$

represent the two-parameter subgroups, and their curves of intersection represent graphically the one-parameter subgroups of G_3(ABll′).

These curves representing the one-parameter subgroups lie entirely in the space above the plane $z=0$. No collineation in G_3(ABll′) with negative value of k belongs to one of its one-parameter subgroups. Consequently one-half of the collineations of the group cannot be generated from infinitesimal collineations of the group.

The point (0, 0, 1) is on every curve of the system representing the subgroups; hence the identical collineation is common to every one-parameter subgroup of G_3(ABll′). Other properties of these groups are easily deduced from the properties of this family of curves.

THEOREM 13. Only one-half of the collineations in G_3(ABll′) belong to its one-parameter subgroups and can be generated from the infinitesimal collineations in G_3(ABll′).

§ 4. SOME SPECIAL SUBGROUPS OF G_3(ABll′).

Two-parameter subgroups of types IX and XII.—The invariant figure of a collineation of type III has three invariant lines, Al, Bl′, and AB. If t or t′ is zero, the one-dimensional transformation along Al or Bl′, respectively, is identical, and the resulting collineation is of type IX. If k and one of the t's vary while the other t is zero, we have a two-parameter subgroup of G_3(ABll′). Thus G_3(ABll′) contains two two-parameter subgroups of type IX.

If $k=1$, the one-dimensional transformation along AB is identical

and all points on the line are invariant; thus a transformation of this kind is of type XII. If t and t′ vary while k=1, we have ∞^2 collineation of type XII, all having the same invariant figure and forming a two-parameter subgroup of G_3(ABll′).

THEOREM 14. The group G_3(ABll′) contains two two-parameter subgroups of type IX and one of type XII.

One-parameter subgroups of types VII and X.—If t=0 and k=1, the collineations in the plane ABl are identical, and the resulting collineations in space are of type VII and form a one-parameter subgroup. In like manner, if t′=0 and k=1, we have another one-parameter subgroup of type VII, ABl′ being the axial plane and B the vertex of its invariant figure. Thus G_3(ABll′) contains two subgroups of type VII.

If t=0 and t′=0 while k varies, the resulting ∞^1 collineations are of type X and form a one-parameter subgroup of this type. Al and Bl′ are the two axes of the skew perspective collineation and k is the parameter.

THEOREM 15. The group G_3(ABll′) contains two one-parameter subgroups of type VII and one of type X.

C.—*On the Group of Collineations G_4(ABlp) of Type IV and its Subgroups.*

§1. THE GROUP G_4(ABlp) AND ITS SUBGROUPS.

The group G_4(ABlp).—A real collineation in space of type IV leaves invariant a figure (ABlp) real in all of its parts, consisting of two planes p and p′ intersecting in a line l, two points A and B and their join l′ in the plane p, A being on l. The one-dimensional transformations along l and l′ are parabolic and hyperbolic, respectively. The two-dimensional transformations in the planes p and p′ are of types III and II, respectively.

A collineation T of type IV is completely determined by its invariant figure (ABlp) and four parameters k, t, n, h; k is the constant cross-ratio along AB, and t, n, h are the three parameters of group of plane collineations of type III in the plane p. These four parameters are all real and may vary simultaneously, thus giving ∞^4 collineations, all having the same invariant figure. These form a four-parameter group G_4(ABlp).

THEOREM 16. The aggregate of all collineations of type IV having the same invariant figure (ABlp) forms a four-parameter group G_4(ABlp).

One-parameter subgroups of G_4(ABlp).—The group contains

∞^3 one-parameter subgroups. To show this, let $k = a^t$ and let a, n and h be constants. There are ∞^1 collineations in the group $G_4(ABlp)$ which satisfy these conditions. In the plane p the plane collineations form a one-parameter group of type III, and in the plane ABl they form a one-parameter group of type II. t is the single independent variable parameter. These ∞^1 collineations in space evidently form a one-parameter group. There are ∞^3 such groups in $G_4(ABlp)$, one for each positive value of a and each real value of n and h. Such a one-parameter group is designated by $G_1(ABlp)anh$. The properties of the group $G_1(ABlp)anh$ are those of a one-parameter parabolic group in one dimension.

THEOREM 17. The group $G_4(ABlp)$ contains ∞^3 one-parameter subgroups $G_1(ABlp)anh$; for each subgroup a, n and h are constants and t is the variable parameter.

Invariant curves and surfaces of $G_1(ABlp)anh$.—The systems of invariant surfaces whose intersections are the path curves of the group $G_1(ABlp)anh$ are determined as follows: Let (ABCD), where C is on l and D in the plane p, be the tetrahedron of reference, and let T be a collineation of the group $G_1(ABlp)$ which transforms the point $P = (x, y, z, w)$ to $P_1 = (x_1, y_1, z_1, w_1)$. From the properties of the invariant figure we easily obtain the following equations of transformation:

$$\frac{x_1}{y_1} : \frac{x}{y} = a^t, \tag{1}$$

$$\frac{y_1}{z_1} - \frac{y}{z} = t, \tag{2}$$

$$\frac{w_1}{z_1} = \frac{w}{z} + nt\frac{y}{z} + \frac{n}{2}t^2 + ht. \tag{3}$$

By eliminating t from these equations taken two and two we obtain the following:

$$x = Ca^{\frac{y}{z}} z, \qquad \text{I}$$

$$\frac{w}{z} - n\frac{\log\frac{x}{z}}{\log a}\frac{y}{z} + \frac{w}{2}\frac{\log^2\frac{x}{z}}{\log^2 a} - h\frac{\log\frac{x}{z}}{\log a} = C, \qquad \text{II}$$

$$\frac{n}{2}y^2 + hyz - wz = Cz^2. \qquad \text{III}$$

These equations represent the invariant families of surfaces whose intersections are the path curves of the group. Equation III is a system of quadric cones with vertices at B and the line AB as a common element.

THEOREM 18. There are three distinct families of ruled surfaces invariant under all the collineations of the group $G_1(ABlp)anh$. Two of these families are transcendental surfaces and one is a family of quadric cones.

Two- and three-parameter subgroups of $G_4(ABlp)$.—If a is con-

stant and n, h, t variable, we have a three-parameter subgroup of $G_4(ABlp)$. All collineations of this group $G_3(ABlp)$ leave invariant the family of surfaces given by l. If n is constant while a, h and t vary, we have another three-parameter group $G_3(ABlp)n$. This group leaves invariant a system of ∞^2 quadric cones. There are thus two systems of three-parameter subgroups of $G_4(ABlp)$, one for each positive value of a and one for each real value of n.

If a and n are both constant while h and t vary, we have a two-parameter subgroup of $G_4(ABlp)$. If h and n are both constant and k and t vary, we have another two-parameter group. The invariant surfaces are easily determined. Thus there are two systems of two-parameter subgroups of $G_4(ABlp)$.

THEOREM 19. The group $G_4(ABlp)$ contains two singly infinite systems of three-parameter subgroups and two doubly infinite systems of two-parameter subgroups.

Since k is both positive and negative, and since only these collineations with positive k can be generated from infinitesimal transformations of the group, it follows that only one-half of the collineations in the group $G_4(ABlp)$ belong to its one-parameter subgroups.

§ 2. SOME SPECIAL SUBGROUPS OF $G_4(ABlp)$.

Three-parameter subgroups of type XIII.—When $k=1$, or, what amounts to the same thing, when $a=1$, the one-dimensional transformation along the line AB is identical, and hence every point on the line is an invariant point; dualistically every plane through the line l is an invariant plane. Therefore, the resulting transformations are of type XIII. Since there are three remaining parameters, n, h, and t, we have a three-parameter subgroup of type XIII.

Three-parameter subgroup of type XI.—If $n=0$, the three-parameter group of type III in the plane p reduces to a two-parameter group of type V. The resulting collineations in space are of type XI, since every point on l is invariant, and form a three-parameter group whose parameters are k, h, and t. Also, if we put $t=0$, $nt \pm 0$, and $ht \pm 0$, the ∞^2 collineations in the plane p are again of type V and form a two-parameter group. Thus we have another three-parameter group of type XI.

Two-parameter subgroup of type VII.—If $a=1$ and $n=0$, all points in the plane ABl are invariant and the collineations are of type VII. They form a two-parameter group of type VII. Also, if $a=1$ and $t=0$, but $nt \pm 0$ and $ht \pm 0$, we have left a two-parameter group of type VII, dualistic to the last.

THEOREM 20. The group $G_4(ABlp)$ contains one three-parameter subgroup of type XIII, two three-parameter subgroups of type XI, and two two-parameter subgroups of type VII.

A NEW THEORY OF COLLINEATIONS IN SPACE, III.

Collineations of Type V in Space.

BY H. B. NEWSON.

A.—*Synthetic Forecast.*

Invariant figure of T.—The fundamental invariant figure of a collineation in space of type V consists* of a plane p, a line l, and a point A; A and l are both in p and A is on l. Let this invariant figure be denoted by (Apl), and let T be a collineation of type V, leaving (Apl) invariant. The collineation T and its invariant figure (Apl) are both self-dualistic. Along the line l and in the pencil of planes through l, T produces a one-dimensional parabolic transformation; in the plane p and in the bundle of rays through A, T produces two-dimensional transformations of type III.

The group $G_6(Apl)$.—The two-dimensional transformations of type III in p, leaving the lineal element Al invariant, are ∞^3 in number and form a three-parameter group with one- and two-parameter subgroups. This three-parameter group leaves invariant the system of ∞^3 conics touching l at A; a two-parameter subgroup leaves invariant a net of ∞^2 of these conics having three points in common at A; a one-parameter subgroup leaves invariant each of a pencil of ∞^1 conics having four points in common at A.

Dualistically the two-dimensional transformations of type III in the bundle of rays through A are ∞^3 in number, and form a three-parameter group with one- and two-parameter subgroups, leaving invariant the system of ∞^3 quadric cones having their vertices at A and touching p along the line l; a two-parameter subgroup leaves invariant a net of ∞^2 of these cones having three elements in common along l; a one-parameter subgroup leaves invariant each of a pencil of ∞^1 cones having four elements in common along A.

These two two-dimensional three-parameter groups are independent of each other, and hence the three-dimensional transformations of type V, leaving (Apl) invariant, depend upon six parameters; *i. e.*, they are ∞^6 in number, and form a six-parameter group $G_6(Apl)$.

THEOREM 1. There are ∞^6 collineations of type V in space leaving the figure (Apl) invariant; these form a six-parameter group $G_6(Apl)$.

*Kansas University Quarterly, Vol. IX, p. 70.

Subgroups of $G_6(Apl)$.—There are two varieties of five-parameter subgroups of G_6(Apl). One of these subgroups consists of all collineations in G_6(Apl) which leave invariant a net of ∞^2 conics in p and the system of ∞^3 cones through A. A subgroup of the other variety consists of all collineations in G_6(Apl) which leave invariant the system of ∞^3 conics in p and a net of ∞^2 cones through A. These two varieties of five-parameter groups form a dualistic pair. There are ∞^1 groups of each variety.

There are three varieties of four-parameter subgroups in G_6(Apl), viz.: (1) All those collineations in G_6(Apl), which leave invariant a net of ∞^2 conics in p and a net of ∞^2 cones through A, form a subgroup; (2) all those collineations, which leave invariant a pencil of ∞^1 conics in p and all cones through A, form a subgroup; (3) all collineations in G_6(Apl), which leave invariant the ∞^3 conics in p and a pencil of ∞^1 cones through A, form a subgroup. The second and third varieties form a dualistic pair and the first is self-dualistic.

There are two varieties of three-parameter subgroups in G_6(Apl), viz.: (1) All collineations in G_6(Apl), which leave invariant a net of ∞^2 conics in p and a pencil of ∞^1 cones through A, form a subgroup: (2) all collineations in G_6(Apl), which leave invariant a pencil of ∞^1 conics in p and a pencil of ∞^2 cones through A, form a subgroup. These two group varieties form a dualistic pair.

There are ∞^4 two-parameter subgroups of G_6(Apl). One of these subgroups consists of all collineations which leave invariant a pencil of conics in p and a pencil of cones through A. There is only one variety of such two-parameter groups.

In the above two-parameter group the parameters of the two-dimensional transformations in p and through A are t and t′, respectively. If we set $t'=gt$ and keep g constant, we obtain a one-parameter subgroup of G_6(Apl).

THEOREM 2. There are nine varieties of subgroups of type V in the group G_6(Apl), viz.: Two varieties of five-parameter subgroups, three of four-parameter subgroups, two of three-parameter subgroups, one of two-parameter subgroups, and one of one-parameter subgroups.

Special subgroups of $G_6(Apl)$.—The group G_6(Apl) contains a number of subgroups composed of collineations of lower types than type V, viz., groups of type XIII, XII, and VII. The three-parameter group of type III in the plane p contains two two-parameter subgroups of elations, viz., $H'_2(A)$ and $H'_2(l)$. The collineations in G_6(Apl), whose plane collineations in p are of type V, are generally of type XIII. Hence, corresponding to the two groups $H'_2(A)$ and $H'_2(l)$ in p, the group G_6(Apl) contains two five-parameter subgroups of type XIII. These five-parameter groups contains four- and three-

parameter subgroups of type XIII; but these details belong more properly to the theory of type XIII, and will be discussed under that heading.

If the transformation in the plane p is identical, the collineations are of type VII, and form a three-parameter group $G_3(p)$. Dualistically, if the two-dimensional transformation through A is identical, the collineations are of type VII in space and form a three-parameter group of type VII, $G_3(A)$. Thus $G_6(Apl)$ contains a dualistic pair of three-parameter subgroups of type VII.

If the one-dimensional transformations along the line l and in the pencil of planes through l are both identical, the collineations are of type XII. Of the ∞^6 collineations in $G_6(Apl)$, ∞^4 satisfy these two conditions, and hence this group contains ∞^4 collineations of type XII. These constitute a four-parameter group of type XII. The constitution of this group will be discussed in the proper place in this series of papers.

THEOREM 3. The group $G_6(Apl)$ contains two five-parameter subgroups of type XIII, two three-parameter subgroups of type VII, and one four-parameter subgroup of type XII.

B.—*Analytic Verification.*

§1. THE SIX-PARAMETER GROUP $G_6(Apl)$.

Analytic expression for T.—Along the line l and in the pencil of planes through l the collineation T produces one-dimensional parabolic transformations whose constants we shall designate by mt and nt, respectively. Let h, k and g be three other constants determining T. Let the tetrahedron of reference (ABCD) be taken so that B is on l, C in the plane p, and D anywhere in space. The plane p is now the plane $z=0$; $y=0$ passes through l; $x=0$ passes through A; and $w=0$ is not specially related to the invariant figure. The collineation T is expressed by the following equations:

$$\frac{y_1}{z_1}=\frac{y}{z}+nt, \tag{1}$$

$$\frac{x_1}{z_1}=\frac{x}{z}+t\frac{y}{z}+\frac{n}{2}t^2+ht, \tag{2}$$

$$\frac{w_1}{z_1}=\frac{w}{z}+mt\frac{x}{z}+\left(\frac{m}{2}t^2+ht\right)\frac{y}{z}+\frac{mn}{6}t^3+\left(\frac{hm+kn}{2}\right)t^2+gt. \tag{3}$$

These equations may be thrown into the form:

$$\frac{x_1}{w_1}=\frac{x+ty+(\frac{n}{2}t^2+ht)z,}{w+mtx+(\frac{m}{2}t^2+kt)y+(\frac{mn}{6}t^3+\frac{(hm+kn)}{2}t^2+gt)z,} \tag{4}$$

$$\frac{y_1}{w_1}=\frac{y+tz,}{w+mtx+(\frac{m}{2}t^2+kt)y+(\frac{mn}{6}t^3+\frac{(hm+kn)}{2}t^2+gt)z,} \tag{5}$$

$$\frac{z_1}{w_1}=\frac{z}{w+mtx+(\frac{m}{2}t^2+kt)y+(\frac{mn}{6}t^3+\frac{(hm+kn)}{2}t^2+gt)z.} \tag{6}$$

That T is correctly expressed by these equations is shown as follows: (1) shows that the one-dimensional transformation in the pencil of planes through l is parabolic; (1) and (2) show that the two-dimensional transformation in the bundle of rays through A is of type III; (4), (5) and (6) show that $A = (0, 0, 0, w)$ is an invariant point; (6) shows that $z = 0$ is an invariant plane; making $z = 0$ in (4), (5), and (6), the modified form of (4) and (5) shows that, in the plane p, l is an invariant line and that the collineation in p is of type III.

Six-parameter group $G_6(Apl)$.—The numbers m, n, h, k, g, t may vary independently, and hence there are ∞^6 collineations of type V, each leaving (Apl) invariant. Let T_1 be a second collineation of the same system, whose constants are m_1, n_1, h_1, k_1, g_1, t_1, and which transforms P_1 to P_2. Eliminating x_1, y_1, z_1, w_1 from T and T_1, we get T_2, whose equations are of the same form as those of T and whose constants are m_2, n_2, h_2, k_2, g_2, t_2. We find the following values of t_2, etc.:

$$t + t_1 = t_2, \tag{7}$$

$$nt + n_1t_1 = n_2t_2, \tag{8}$$

$$mt + m_1t_1 = m_2t_2, \tag{9}$$

$$\frac{nt^2 + 2ntt_1 + n_1t_1^2}{2} + ht + h_1t_1 = \frac{n_2}{2}t_2^2 + h_2t_2, \tag{10}$$

$$\frac{mt^2 + 2m_1tt_1 + m_1t_1^2}{2} + kt + k_1t_1 = \frac{m_2}{2}t_2^2 + k_2t_2, \tag{11}$$

$$\frac{mnt^3 + 3m_1nt^2t_1 + 3m_1ntt_1^2 + m_1n_1t_1^3}{6} + \frac{(hm + kn)t^2 + 2(hm_1 + k_1n)tt_1 + (h_1m_1 + k_1n_1)t^2}{2} +$$

$$gt + g_1t_1 = \frac{m_2n_2}{6}t_2^3 + \frac{h_2m_2 + k_2n_2}{2}t_2^2 + g_2t_2. \tag{12}$$

These six equations show that all the parameters are essential, and that we have a six-parameter group; thus verifying theorem 1.

§ 2. One-parameter Subgroups of $G_6(Apl)$.

The one-parameter group $G_1(Apl)$.—If we keep m, n, h, k and g fixed and let t alone vary, we select thus from $G_6(Apl)$ ∞^1 collineations which form a one-parameter subgroup of $G_6(Apl)$. This follows from the fact that under these conditions there are no longer six independent equations (7)–(12), but only one, viz., (7). The parameter of the group is t, and the equation $t + t_1 = t_2$ tells us that its properties are those of a one-dimensional parabolic group. Evidently there are ∞^5 such subgroups of $G_6(Apl)$, one for each value of m, n, h, k, g. Such a group is designated by $G_1(Apl)$. This is the only variety of one-parameter subgroups contained in $G_6(Apl)$; for if any other parameter besides t be made to vary alone and the other five be kept fixed, the resulting ∞^5 collineations do not form a group. Equations (7)–(12) confirm this statement.

Invariant curves and surfaces of $G_1(Apl)$.—The families of sur-

faces invariant under the collineations of the group $G_1(Apl)$ are obtained by eliminating t from all pairs of equations formed from (1), (2), and (3). From (1) and (2) we get:

$$f(x_1, y_1, z_1) \equiv f(z, y, z) \equiv \tfrac{1}{2}y^2 + hyz - nxz - Cz^2 = 0. \qquad \text{I}$$

From (1) and (3), and making use of the identity in I, we get:

$$f(x_1, y_1, z_1, w_1) \equiv f(z, y, z, w) \equiv \tfrac{m}{3}y^3 + \tfrac{hm - kn}{2}y^2z - mnxyz - gnyz^2 + n^2wz^2 - Cz^3 = 0. \qquad \text{II}$$

From (2) and (3), and using the identities in I and II, we get:

$$f(x_1, y_1, z_1, w_1) \equiv f(x, y, z; w) \equiv \left\{ x\left[\tfrac{m}{6}(hz + y) + \tfrac{kn}{2}z\right] - \tfrac{nwz}{2} \right\}^2 + \left\{ x\left(gz + ky + \tfrac{2mx}{3}\right) - w(hz + y) \right\}$$
$$\left\{ \tfrac{nz}{2}\left(gz + ky + \tfrac{2mx}{3}\right) - (hz + y)\left[\tfrac{m}{6}(hz + y) + \tfrac{kn}{2}z\right] \right\} - Cz^4 = 0. \qquad \text{III}$$

Making $z = 0$ in equations (4), (5), and (6), the last disappears, and the modified forms of (4) and (5) can be put into the form:

$$\begin{cases} \dfrac{x_1}{y_1} = \dfrac{x}{y} + t \\ \dfrac{w_1}{y_1} = \dfrac{w}{y} + mt\dfrac{x}{y} + \dfrac{m}{2}t^2 + kt. \end{cases} \qquad (10)$$

Eliminating t from these, we have the following equation of the invariant conics in the plane p:

$$f(x_1, y_1, w_1) \equiv f(x, y, w) \equiv \tfrac{m}{2}x^2 + kxy - yw = Cy^2. \qquad \text{IV}$$

In I, II, III, and IV, C is the arbitrary parameter of the family of surfaces.

Equation I represents a system of quadric cones having A for a common vertex, l for a common element, and p for a common tangent plane. Equation II represents a family of cubic ruled surfaces having l for a common line and the plane p for an inflectional tangent plane along the line l. The curves of intersection of I and II are the path curves of the group $G_1(Apl)$.

The two families of surfaces have the line l in common; hence their curves of intersection are of a lower degree than the sixth. Taking a section of both surfaces by the plane $w = 0$, we get the following system of curves:

$$\tfrac{1}{2}y^2 + hyz - nxz = Cz^2 \text{ and } \tfrac{m}{3}y^3 + \tfrac{hm - kn}{2}y^2z - mnxyz - gnyz^2 = Cz^3. \qquad (11)$$

Eliminating x from these equations, we find three points of intersection exclusive of those on l. Hence the intersections of the systems of surfaces I and II are ∞^2 twisted cubics in space. They all pass through A and have l for a common tangent at A.

THEOREM 4. The group $G_6(Apl)$ contains ∞^5 one-parameter sub-

groups; the path curves of one of these subgroups are twisted cubics; each subgroup leaves invariant a family of quadric cones, a family of cubic cones, and a family of quartic surfaces.

§ 3. Other Subgroups of $G_6(Apl)$.

Five-parameter subgroups of $G_6(Apl)$.—If m be kept fixed and the other five parameters be allowed to vary, the resulting collineations form a five-parameter group $G_6(Apl)m$. If we make $m_1 = m$ a constant in equations (7)–(12), we find also $m_2 = m$, and equation (9) is no longer independent. The remaining five equations show the five-parameter group. There are ∞^1 such subgroups in $G_6(Apl)$, one for each real value of m. The group $G_5(Apl)m$ leaves invariant a net of ∞^2 conics in the plane p.

In exactly the same way it may be shown that when $n_1 = n$ also $n_2 = n$, and we have another singly infinite system of five-parameter subgroups $G_5(Apl)n$. The group $G_5(Apl)n$ leaves invariant a net of ∞^2 quadric cones with their vertices at A.

Four-parameter subgroups of $G_6(Apl)$.—If n and h are both constant while the other four parameters vary, the remaining ∞^4 collineations form a four-parameter subgroup of $G_6(Apl)$. This is shown by the vanishing of equations (8) and (10); the remaining four show a four-parameter subgroup. There is a doubly infinite system of these four-parameter groups, one for each value of n and h. One of these groups, $G_4(Apl)nh$, leaves invariant a singly infinite system of quadric cones contained in I.

If m and k are both constant while the other four parameters vary, the remaining ∞^4 collineations form a four-parameter group $G_4(Apl)mk$. This is shown by the vanishing of equations (9) and (11); the remaining four equations show the four-parameter group. There is a doubly infinite system of these four-parameter subgroups, one for each value of m and k. The group $G_4(Apl)mk$ leaves invariant a pencil of conics in the plane p.

If m and n are both constant while h, k, g, t vary independently, we have another four-parameter subgroup of $G_6(Apl)$. The six equations (7)–(12) reduce to

$$t + t_1 = t_2,\ ht + h_1t_1 = h_2t_2,\ kt + k_1t_1 = k_2t_2, \text{ and}$$
$$\frac{(hm + kn)t^2 + 2(h_1m + k_1n)tt_1 + (h_1m + k_1n)t^2}{2} + gt + g_1t_1 = \frac{h_2m + k_2n}{2}t_2^2 + g_2t_2.$$

The group $G_4(Apl)mn$ leaves invariant a net of ∞^2 conics in p and a net of ∞^2 cones through A. There is a doubly infinite system of these four-parameter subgroups, one for each value of m and n.

Three-parameter subgroups of $G_6(Apl)$.—There are two triply infinite systems of three-parameter subgroups of $G_6(Apl)$; one of these

results when m, n and h are constant, the other when m, n and k are constant. In the first case the group G_3(Apl)mnh leaves invariant a net of conics in p and a pencil of cones through A; in the second case the group G_3(Apl)mnk leaves invariant a pencil of conics in p and a net of cones through A.

Two-parameter subgroup of $G_6(Apl)$.—When m, n, h, k are all constant and g and t alone vary, the ∞^2 collineations form a two-parameter subgroup of G_6(Apl). Evidently there is a quadruply infinite system of these two-parameter groups. The group G_2(Apl)mnhk leaves invariant a pencil of conics in p and a pencil of cones through A.

THEOREM 6. The group G_6(Apl) contains two singly infinite systems of five-parameter subgroups, three doubly infinite systems of four-parameter subgroups, two triply infinite systems of three-parameter subgroups, and one quadruply infinite system of two-parameter subgroups. These are characterized by $m=c$; $n=c$; $m=c$ and $n=c$; $n=c$ and $h=c$; $m=c$ and $k=c$; $m=c, n=c, h=c$; $m=c, n=c, k=c$; $m=c, n=c, h=c, k=c$.

§ 3. SOME SPECIAL SUBGROUPS OF G_6(Apl).

Groups of type XIII in $G_6(Apl)$.—For any constant value of m we have a five-parameter subgroup of G_6(Apl); for the special value $m=0$ the subgroup requires special attention. Let $m=0$ in equation IV; it reduces to $y(kx-w-Cy)=0$, *i. e.*, the conics in p break up into the invariant line $y=0$ and the pencil of lines $kx-w-Cy=0$. Hence the collineation in the plane p is of type V; dualistically the collineation in the bundle through III is also of type V. Thus it must have a pencil of invariant planes corresponding to the line of invariant points in p. The collineations in space are therefore of type XIII, and these form a five-parameter group of this type.

In like manner, when $n=0$ the two-dimensional collineations in p and through A are of type V and the three-dimensional collineations are of type XIII. They form a five-parameter subgroup of this type.

Each of these five-parameter subgroups of type XIII contains a singly infinite system of four-parameter subgroups and a doubly infinite system of three-parameter subgroups of type XIII. The fundamental group of XIII is three-parametered. The discussion of the details of these groups belongs more properly to the theory of type XIII and will be given in its proper place.

Subgroup of type XII in $G_6(Apl)$.—When $m=0$ and $n=0$, the one-dimensional transformations along l and in the pencil of planes through l are both identical; hence all points on l and all planes through l are invariant. The collineations in the planes through l are

all of type V; hence the collineations in space are of type XII. There are ∞^4 such collineations in G_6(Apl), and they form a four-parameter subgroup of type XII.

Subgroups of type VII in G_6(Apl).—When n, m and k are all zero, the transformation in the plane p is identical, and the remaining collineations are of type VII and form a three-parameter group. Dualistically there is a three-parameter group of type VII which leaves invariant every ray through A. This results when $m=0$, $n=0$, and $h=0$. The subgroups of these two three-parameter groups will not be discussed here.

THEOREM 4. The group G_6(Apl) contains two five-parameter subgroups of type XIII, one four-parameter subgroup of type XII, and two three-parameter subgroups of type VII.

The theory sketched in this paper holds equally well whether the collineations are real or complex.

Table of groups of type V.—The following is a complete list of the continuous groups of collineations of type V:

(1) G_6(Apl).
(2) G_5(Apl)m.
(3) G_5(Apl)n.
(4) G_4(Apl)mn.
(5) G_4(Apl)nh.
(6) G_4(Apl)mk.
(7) G_3(Apl)mnh.
(8) G_3(Apl)mnk.
(9) G_2(Apl)mnhk.
(10) G_1(Apl).

COCCIDÆ OF KANSAS, IV.

Additional Species, Food-plants and Bibliography of Kansas Coccidæ, with Appendix on other Species Reported from Kansas.

BY S. J. HUNTER. With plate VIII.

A.—Additional Species.

Kermes pubescens **Bogue. Plate VIII, fig. 1.**

On white oak, Lawrence, Douglas county.

Kermes nivalis **King and Ckll. Plate VIII, fig. 2.**

On white oak, Lawrence, Douglas county.

Orthezia graminis **Tinsley. Plate VIII, figs. 3, 4.**

On goldenrod (*Solidago* sp.), Blue Rapids, Marshall county. Mrs. S. G. Cady, collector.

B.—Food-plants of Kansas Coccidæ.

In order to understand the significance or importance of the food-plants of Coccidæ, or scale-insects, some knowledge of the life and habits of the insect is necessary. Scale-insects are plant parasites and locate themselves upon the bark or outer covering of the plants. They have long, slender beaks, which they are able to insert into the tissues of the plants and draw therefrom the plant juices. Some scale-insects choose but a single host-plant, and others seem to be able to subsist upon a very great variety of plants. This adaptability to various food-plants has much to do with the numbers of the several species in existence. It is evident that if a species of insect has to depend exclusively upon a single plant variety, the chances of life for this insect would decrease with a decrease in numbers of the host; while, on the other hand, scale-insects which have the power to adapt themselves to a number of plants have greater chances of life and better opportunities for numerical increase. In animal parasitism the parasite tends to increase as the host increases. The increase of the parasite, however, is generally in a greater ratio than the increase of the host, so that the parasite frequently becomes so numerous as to destroy or greatly curtail the increase of the host, and then the parasite must succumb likewise, or adapt itself to new conditions. Such relations between host and parasite exist to a certain extent be-

tween the scale-insects and their respective hosts. A study of the food-plants, therefore, of the scale-insects, becomes a matter of considerable importance in determining the continuation of a species and the possibilities of its numerical increase. The insects herein discussed have been found on certain food-plants in Kansas. They have likewise been found by other authorities on other food-plants in other parts of the globe. A record of each of these discoveries is given in the following pages:

Aspidiotus forbesi **Johns.**

Honey-locust, *Gleditschia tricanthos* (Johns.), Ckll., Proc. Nat. M., XIX, p. 738.
Peach, *Prunus*, Ckll., ibid., p. 740.
Apricot, *Prunus armeniaca*, Johns., Ent. News, p. 151 (1896).
Garden currant, *Ribes rubrum*, ibid.
Ash, Osborn, Proc. Iowa Acad. Sci., p. 229 (1897).
Crab-apple, Hunter, K. U. Quart., VIII., No. 1, p. 4 (Jan. 1899).
Pear, Johns., Ill. Sta. Lab. Nat. Hist., IV, p. 381.
Plum, ibid.
Apple, ibid.
Quince, ibid.
Currant, ibid.
Wild and cultivated cherry, *Amygdalus persica*, Leonardi, Riv. di Pat. Veg., p. 43 (1897).
Acer fraxinus, ibid.
Staphylea trifoliata, ibid.

Aspidiotus ancylus **Putnam.**

Linden, Comstock, 2d Corn. Univ. Rept., p. 140.
Box-elder, *Negundo* sp., Ckll., Proc.Nat. M., XIX, p. 735.
Apricot, *Prunus armeniacum*, Ckll., Proc. Nat. M., XIX, p. 741.
Plum, *Prunus domestica*, in Santa Fé, N. M.. Ckll., ibid.
Black currant, *Ribes* sp., Ckll., Am. Nat., p. 731 (1895).
Oaks, Comstock, 2d Corn. Univ. Rept., p. 140.
Beech, ibid., p. 139.
Water locust, ibid., p. 140.
Ilex verticillata, Felt., Bull. N. Y. Mus., VI, No. 31, p. 617 (1900).
Hemlock, ibid.
Mountain ash, ibid.
Willow, Felt., Bull. N. Y. Mus., V, No. 23, p. 261 (1898).
Apple, ibid.
Elm, ibid.
Pear, Gillette and Baker, Colo. Agr. Exp. Sta., Bull. 31, Tech. Sér., No. 1, p. 128.
Black maple, Newell, Cont. Iowa St. Col. Agr., No. 3, p. 8.
Birch, ibid.
Snowball, ibid.
Gleditschia tricanthos, Ann. Mag. Nat. Hist., p. 323 (1898).
Quercus wrightii, Ckll., Can. Ent., vol. 28, p. 226 (1896).
Cottonwood, Gillette, Colo. Agr. Col. Ex. Sta., Bull. No. 38, 1898, p. 36.
Spirea arnicus, King, Can. Ent., p. 226, vol. —.*

* The separates of the Canadian Entomologist have no date marks. It has been, therefore, impossible to locate accurately all references as to recent numbers of this magazine, since the department numbers are at the bindery.

Honey-locust, King, Can. Ent., p. 226, vol. —.
Quince, ibid.
Maple, Putnam, Proc. Dav. Acad. Nat. Sci., vol. II, p. 346.
Peach, Comstock, U. S. Dept. Rept. Com. Agr., 1880, p. 59.
Osage orange, ibid.
Hackberry, ibid.
Bladder-nut, ibid.
Ash, ibid.
Chestnut, in U. S. Dept. Agr. Coll. Howard.
Cratægus, ibid.
Elagnus reflexa, ibid.
Lonicera, ibid.
Syringa, ibid.
Prunus pissardi, ibid.

Aspidiotus uvæ Comst.

Grape, Comst., 2d Rept. Dept. Ent. Cor. Exp. Sta., p. 71, 1883.
Hickory, ibid.

Aspidiotus osborni Newell.

Quercus alba, Hunter, K. U. Quart., vol. VIII, No. 1, p. 6.
Ironwood, *Ostrya virginica*, Newell, Cont. Iowa St. Col. Agr., No. 3, p. 7.

Aspidiotus ulmi Johns.

White elm, *Ulmus americana*, Johns., Ill. St. Lab. Nat., vol. IV, art. 13, p. 388.
Slippery or Red elm, *Ulmus fulva*, Hunter, K. U. Quart., VIII, No. 1, p. 6.
Catalpa, Hunter, K. U. Quart., VIII, No. 1, p. 6.

Aspidiotus fernaldi Ckll., subsp. *albiventer*.

Maple, *Acer* sp., Hunter, K. U. Quart., VIII, No. 1, p. 7.

Aspidiotus obscurus Comst.

Willow oak, Comst., 2d Corn. Univ. Rept., p. 140.
Black oak, *Quercus* sp., Hunter, K. U. Quart., VIII, No. 1, p. 7.
Chestnut, Hunter, found in Miami county, Kansas, June, 1901.

Aspidiotus juglans-regiæ Comst.

Peach, *Prunus* or *Amygdalus persica*, Ckll., Proc. Nat. M., XIX, p. 740.
English walnut, Comst., 2d Corn. Univ. Rept., p. 61.
Prune, *Prunus* sp. (Ehrhorn), Ckll., Can. Ent., 1895, p. 260.
Crab-apple, Hunter, K. U. Quart., vol. VIII, No. 1, p. 8.
Pear, Comst., 2d Corn. Univ. Rept., p. 62.
Cherry, ibid.
Locust, ibid.
Ash, Fernald, Pa. Dept. Agr., Bull. No. 43, p. 20.
Currant, Osborn, Proc. Iowa Acad. Sci., vol. V, p. 230, 1897.

Aspidiotus perniciosus.

Cherry, Howard, Bull. 12, U. S. Dept. Agr., Div. Ent., p. 13.
English huckleberry, ibid.
Black walnut, ibid.
Japan walnut, ibid.
English willow, ibid.

Golden willow, Bull. 12, U. S. Dept. Agr., Div. Ent., p. 13.
Rocky Mountain dwarf cherry, ibid.
Flowering quince, ibid.
Japanese quince, ibid.
Strawberry, ibid.
Black currant, ibid.
Lombardy poplar, ibid.
Carolina poplar, ibid.
Golden-leaved poplar, ibid.
Silver maple, ibid.
Cut-leaved birch, ibid.
Mountain ash, ibid.
Milkweed, ibid.
Catalpa speciosa, ibid.
Actinidia, ibid.
Citrus trifoliata, ibid.
Red dogwood, ibid.
Snowball, *Viburnum*, ibid.
Juneberry, ibid.
Loquat, ibid.
Laurel, ibid.
Akebia, ibid.
White currant, Lochhead, Ont. Dept. Agr., p. 31, Mar. 1900.
White ash, ibid.
Ornamental birch, ibid.
Maple leaf, ibid.
Rhubarb, ibid.
Hemp, ibid.
Lamb's-quarters, ibid.
Garden knotweed, ibid.
Mustard, ibid.
Beggar-ticks, ibid.
Goose-foot, ibid.
Ragweed, ibid.
Sunflower, ibid.
Weeping willow, Smith, Rept. N. J. Agr. Col. Exp. Sta., p. 547, 1896.
Laurel-leaved willow, ibid.
Kilmarnock willow, ibid.
Linden, ibid.
English walnut, ibid.
Flowering currant, ibid.
Euonymus, ibid.
Gooseberry, ibid.
Persimmon, Ebenaceæ, ibid.
Acacia, Leguminoseæ, ibid.
Elm, ibid.
Osage orange, ibid.
Pecan, ibid.
Hickory, ibid.
Alder, ibid.
Chestnut, ibid.
Oak, ibid.

Sumac, Smith, Rept. N. J. Agr. Col. Exp. Sta., p. 547, 1896.
Grape, ibid.
Catalpa bignoniodes, (Howard), Ckll., U. S. Dept. Agr., Div. Ent., Tech. Ser., No. 6, p. 17.
Crab-apple, Ckll., U. S. Dept. Agr., Div. Ent., Tech. Ser., No. 6.
Bartlett pear, ibid.
Dwarf Duchess pear, ibid.
Pyrus japonica, ibid.
Satsuma plum, ibid.
Prunus pissardi, ibid.
Prunus maritimi, ibid.
Citrus albapanetatus, ibid.
Cottonwood, ibid.
European linden, ibid.
Apple, *Pyrus malus*, Comst., 2d Corn. Univ. Rept., p. 140.
Apricot, *Prunus armeniaca*, ibid.
Crab grass, Johnson, Bull. No. 57, Md. Agr. Exp. Sta., p. 61, 1898.
Peach, Ckll., Proc. Nat. M., XIX, p. 740.
Rose, Ckll., Amer. Nat., p. 726, 1895.
Almond, Fernald, Bull. 36, Mass. Agr. Col., p. 19.
Spirea, ibid.
Raspberry, ibid.
Hawthorn, ibid.
Cotoneaster, ibid.

Aspidiotus greenii Ckll.

Palm, *Howea belmoreana*, Hunter, K. U. Quart., VIII, No. 1, p. 11.*
Banana, Townsend, An. & Mag. Nat. Hist., ser. 7, III, p. 169.*
Cycas (Green), Ckll., Bull. Div. Ent., Tech. Ser., No. 6, p. 27.*
House palm, Ckll., Ent. Mo. Mag., XXXIV, pp. 184, 185, Aug. 1898.*
Palm, *Seaforthia elegans*, Ckll., Entom., XXXII, p. 93, Apr. 1899.*
Guava, Ckll. and Parrott, Industrialist, p. 277, May, 1899.*
Vine leaves, ibid.*

Aspidiotus hederæ Ball., var. *nerii* Bouche.

Madrone, *Arbutus menziesii*, Coquillett, Bull. 26, Div. Ent. U. S. Dept. Agr., p. 20.
Century plant, *Agave americana*, ibid.
Lilac, *Syringa vulgaris*, ibid.
Nightshade, *Solanum douglasii*, ibid.
China tree, ibid.
English ivy, ibid.
Oak, *Quercus agrifolia*, ibid.
Arborvitæ, *Thuja occidentalis*, on *cones of*, ibid.
Acacia, Comstock, 2d Rept. Corn. Univ. Exp. Sta., 1883, p. 13.
Cherry, ibid.
Currant, ibid.
Grass, ibid.
Clover, ibid.
Orange tree, ibid.
Lemon, ibid.
Maple, ibid.

*Those succeeded by a star were kindly furnished by Mr. Kotinsky, through Dr. Howard.

Melia, Comstock, 2d Rept. Corn. Univ. Exp. Sta., 1883, p. 13.
Oleander, ibid.
Plum, ibid.
Yucca, ibid.
Coprosma lucida, Maskell, Sca. Ins. N. Z., p. 45.
Corynocarpus lævigatæ, ibid.
Orchids, Gardners' Chronicle, May 6, 1893, p. 548.
New Zealand flax, *Phormium tenax*, Comst., 2d Corn. Rept., p. 140.
Holly, Comst., ibid.
Boxwood, Comst., 2d Corn. Rept., p. 139.
Oleander (Ckll.), Gillette, Colo. Agr. Col. Ex. Sta., Bull. No. 31, Tech. Ser., No. 1, p. 128.
Orange (Ckll.), Gillette, ibid.
Lemon (Ckll.), Gillette, ibid.
Fracaena (Ckll.), Gillette, ibid.
Olive, *Olea europea*, Ckll., Jour. Trin. Nat. Fld. Club, vol. II, No. 12, p. 307.
Magnolia grandiflora, ibid.
Rose, Townsend, Tech. Ser., No. 4, Div. Ent., p. 11.
Palo dulce, ibid.
Lace fern, Johnson, Div. Ent., n. ser., No. 6, pp. 75-78 (1896).
Sweet lime (fruit), Cockerell, Ann. Mag. Nat. Hist., p. 167, Feb. 1899.
Pinus (leaves), ibid.
Ivy, *Hedera helix*, Saccardo, Rivista Pat. Veg., IV, p. 50, 1895 (1895-'96).
Nerium oleander, ibid, p. 49.
"Trueno," Cockerell, Biol. Cent. Amer., II, part 2, p. 20, Dec. 1899.
Palms, King, Can. Ent., XXXI, p. 225, Aug. 1899.
Cycas, ibid.
Heather, *Erica*, ibid.
Cycas revoluti, Osborn, Proc. Iowa Acad. Sci., V, p. 230, 1897 (1898).
Arica, Cockerell, Jour. Inst. Jamaica, I, p. 255, No. 55, Apr. 1893.
Tea, Green, Indian Mus. Notes, IV, No. 1, p. 4, 1896 (reprint, p. 3).
Loranthus, ibid.
Dalbergia, ibid.
Aristea major, Indian Ent. Mo. Mag., XXXIII, p. 69, Mar. 1897.
Aucuba, Douglas, Ent. Mo. Mag., XXIII, pp. 151, 152, Dec. 1896.
Azalea, ibid.

Aspidiotus æsculi **Johns., subsp.** ***solus*****, subsp. nov. Hunter.**

Juglans nigra, Hunter, K. U. Quart., VIII, No. 1, p. 12.

Mytilaspis pomorum **Bouche.**

Apple, Comst., 2d Corn. Univ. Rept., p. 139.
Basswood, Ckll., Proc. Nat. M., XI, p. 730.
Bladder-nut, *Staphylea* (Comst.), ibid., p. 736.
Broom, *Cytisus scoparius*, Ent. Mo. Mag., p. 138, 1893.
Cultivated locust, *Robinia pseudacacia*, Ckll., Proc. Nat. M., XIX, p. 738.
Hawthorn, *Cratægus oxycantha*, ibid., p. 744.
Wild gooseberry, *Ribes cynosbati*, Country Gentleman, p. 27, Jan. 16, 1895.
Cornus californicus (Harvey), Ckll., Proc. Nat. M., XIX, p. 735.
Pear, Maskell, Scale Insects of N. Z., p. 52 (1887).
Plum, ibid.
Peach, ibid.

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Fraxinus americanus, Country Gentleman, p. 27, Jan. 10, 1895.
Planera (Comst.), Ckll., Proc. Nat. M., XIX, 766.
Yucca, Comst., 2d Corn. Univ. Rept., p. 140.
Poplar, Bull. N. Y. Mus., 13th Rept. St. Ent. p. 374, 1897.
Magnolia, umbrella, ibid.
Privet, Bull. N. Y. Mus., V, No. 23, p. 261, Dec. 1898.
Quince, Hunter, K. U. Bull. Dept. Ent., p. 25, 1898.
Hop-tree, Hunter, ibid.
Buckthorn, ibid.
Raspberry, ibid.
Grape-vines, Berlese and Leonardi, Rivista Pat. Veg., III, p. 347, 1895 (1894-'95).*
Citrous plants, ibid.*
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Amorpha (an exotic), ibid.
Water locust, ibid.
Raspberry, ibid.
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Lonicera pulverulenta, ibid.
Planera kaku, ibid.
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Cornus californicus, Ckll., Can. Ent., XXVII, pp. 259, 260, 1895.*
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Spiræa aruncus, ibid.
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Ailanthus glandulosus, Maskell, Ent. Mo. Mag., XXXIII, p. —, Nov. 1897.*
Stillingia sebifera, ibid.
Common broom, *Sarothamnus scoparius*, Newstead, Ent. Mo. Mag., XXIX, p. 138, 1893.*
Cytisus nubigenus, ibid.*
Cocoa-palm leaves, Morgan, Ent. Mo. Mag., XXV, p. 350, Aug. 1889.*
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Horse-chestnut, ibid.
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Honeysuckle, ibid.
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Cottonwood, ibid.
Willow, ibid.
Wild red cherry, Lochhead, Ont. Dept. Agr., p. 41, Mar. 1900.
Grape, ibid.
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Birch, ibid.
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Walnut, Smith, N. J. Agr. Exp. Sta., p. 140.
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Diaspis snowii **Hunter.**

Salix nigra, Hunter, K. U. Quart., VIII, No. 1, p. 15.

Lecanium (Macluræ) aurantiacum **Hunter.**

Osage orange, *Maclura aurantiaca*, Hunter, K. U. Quart., VIII, No. 2, p. 68.

Lecanium canadense **Ckll.**

Ulmus racemosa, Ckll., Can. Ent., p. 254, 1895.
Ulmus americana (Glenn), Hunter, K. U. Quart., VIII, No. 2, p. 69.

Lecanium kansasense **Hunter.**

Cersis canadensis, Hunter, K. U. Quart., VIII, No. 2, p. 69.
Juglans nigra, Hunter, K. U. Quart., VIII, No. 2, p. 70.
Ulmus fulva, Hunter, ibid.

Lecanium cockerelli, **nov. sp., Hunter.**

Ulmus americana, Hunter, K. U. Quart., VIII, No. 2, p. 70.
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Oak, *Quercus* sp., King, Can. Ent., vol. —, p. 252.
Sweet fern, *Comptonia asplenifolia*, ibid.
Plum, Hunter, K. U. Quart., vol. IX, Ser. A, No. 2, p. 107, Apr. 1900.
Hickory, ibid.
Populus sp., King, Psyche, IX, p. 117, Oct. 1900.
Wild crab-apple on University campus, Hunter.

Lecanium armeniacum **Craw.**

Plum, Hunter, K. U. Quart., VIII, No. 2, p. 71.
Grape-vine, Country Gentleman, June 16, 1898.
English gooseberry, Felt., Bull. N. Y. Mus., VI, No. 31, p. 617.
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Prune, ibid.
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Pittosporum (Coq.), Ckll., Proc. Nat. M., XIX, p. 727.
Tea plant, *Camellia*, ibid., p. 728.
Abutilon, Gillette and Baker, ibid., p. 729.
Citrus tree, Comst., 2d Corn. Univ. Rept., p. 139.
Holly, Ckll., Proc. Nat. M., XIX, p. 733.
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Rhus integrifolia (Coq.), Ckll., Proc. Nat. M., XIX, p. 736.
Schinus molle, ibid., p. 737.
Cultivated locust, *Robinia pseudacacia*, ibid., p. 738.
Apricot, Coq., Bull. 26, Div. Ent. U. S. Dept. Agr., p. 26.
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Lombardy poplar, ibid.
Orchid, *Dendrobium*, Ckll., Trans. Amer. Ent. Soc. 1893, p. 40.
Hippeastrum equestre, Ckll., Proc. Nat. M., XIX, p. 777.
Palm, Ckll., Ins. Life, VI, p. 103.
Calla lily, Coq., Bull. 26, Div. Ent. U. S. Dept. Agr., p. 26.
English ivy, *Hedera helix*, Hunter, K. U. Quart., VIII, No. 2, p. 75.
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Rubber tree, *Ficus macrophylla*, Coq., Bull. 26, U. S. Dept. Agr., Div. Ent., p. 26.
Euonymus, ibid.
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Rhamus crocea, ibid.
Heteromeles arbutifolia, ibid.
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Ficus elastica, ibid.
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Carica papaia, Maskell, Ent. Mo. Mag., XXXIII, p. 243, Nov. 1897.*
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Tea plant, *Camellia*, Cotes, Ind. Mus. Notes, 1895.
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Habrothamuus elegans, ibid.
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Myosporum, ibid.
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Beech, ibid.
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Parlatoria pergandei.

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The following synonymy is taken from C. L. Marlatt's MSS. of March 2, 1900:

Pergandei Comst. (merges into *proteus* Curt.)
Syn. var. *camelliæ* Comst.
" var. *crotonis* Ckll.
" var. *affinis* Newst.
" var. *calianthina* B. & L. (not seen; ? var. *theæ* Ckll.)
" var. *theæ* Ckll. (? *calianthina* B. & L.)
" (?) *dryandræ* Full.
" var. *euonymi* Ckll.
" *myrtus* Mask.
" (?) *pittaspori* Mask.
" *sinensis* Mask.
" var. *viridis* Ckll.
" var. *virescens* Mask.
" *viridis* Full.

Parlatoria pergandei Morgan, La. Sta., Bull. 28, 2d ser., pp. —, (18—).
La. Sta., Sp. Bull., pp. —, (18—).
Parlatoria proteus Curt., var. *pergandei* Comst., King. Can. Ent., vol. —, p. 228.
Parlatoria pergandei Reh., Zeitschrift für Entom., vol. V, p. 162, June, 1900.*
do Ckll., Amer. Nat., July, 1897, p. 592.*
do Craw, Rept. Bd. Hort. Cal., vol. V, pp. 41, 42, pl. VIII, fig. 5, 1895-'96.*

Kermes nivalis.

Kermes nivalis King and Ckll., Ann. and Mag. Nat. Hist., ser. 7, vol. II, 1898.
do King, Can. Ent., p. 139, (1899), vol. XXXI.
Psyche, p. 80, July, 1900.
do Ckll., Psyche, IX, p. 44, Apr. 1900.*

Kermes pubescens.

Kermes pubescens Bogue, Can. Ent., vol. 30, No. 7, p. 172, (1898).
do King, Can. Ent., p. 139.
Psyche, p. 80, July, 1900.
do Ckll, Psyche, IX, p. 44, Apr. 1900.*

Orthesia graminis.

Orthesia graminis Tinsley, Can. Ent., vol. 30, No. 1, p. 13, (1898).

NOTE.—To the list of food-plants Miss Etta Willett, a student of this department, added a number, an exact account of which was not taken at the time.

APPENDIX.

Other Coccidæ Reported from Kansas.

Kermes concinnulus Ckll., Cockerell, on oak, Can. Ent., p. 172, (1898).
Aspidiotus marlatti Parrott, on *Andropogon scoparius* and *Andropogon furcatus*, Can. Ent., p. 282, (1899).
Antonina nortoni Parrott and Ckll., on *Bouteloua racemosa*, Can. Ent., Oct. (1899).
Lecanium longulum Dougl., Parrott, Industrialist, p. 39, (1899).
Lecanium pruinosum Comst., ibid.
Aspidiotus cyanophylli Sign., ibid.
Aulacaspis boisduvalii Sign., ibid.
Parlatoria proteus Curt., ibid.
Aspidiotus helianthi Parrott, Can. Ent., vol. 31, p. 176 (1899).
Antonina boutelouæ Parrott, on *Bouteloua hirsuta*, Parrott, Kan. Agr. Coll. Bull. No. 98, p. 138, (1900).
Antonina purpurea Sign., on *Milium* and *Agripyrum*, ibid.
Antonina graminis Parrott, on *Eragrotis trichodes*, *Bulbilis dactyloides*, *Paspalum ciliatifolium*, ibid., p. 140.
Gymnococus nativus Parrott, on *Sporobolus cryptandrus*, ibid., p. 143.
Pseudolecanium obscurum Parrott, on *Androgopon scoparius* and *Sporobolis longifolius*, ibid., p. 145.
Pseudolecanium californicum Ehrhorn, on *Androgopon furcatus*, ibid., p. 145.
Ericoccus kemptonia Parrott, ibid., p. 144.
Pulvinaria hunteri, on maple, King, MS.

LABORATORY OF COMPARATIVE ZOOLOGY AND ENTOMOLOGY,
July, 1901.





FIG. 1.—*Kermes pubescens* on *Quercus alba*, Lawrence.



FIG. 2.—*Kermes nivalis* on *Quercus alba*, Lawrence.

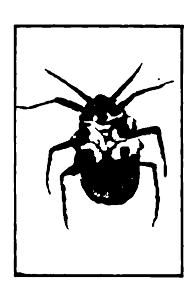


FIG. 3.—Ventral view of *Orthezia graminis* on goldenrod (*Solidago* sp.), without posteriorly elongated egg sac. Mrs. S. G. Cady, col., Blue Rapids, Marshall county.



FIG. 4.—Dorsal view of *Orthezia graminis*, showing posteriorly elongated egg sac.

Photographs by the author.



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BIBLIOGRAPHY OF SCIENTIFIC PUBLICATIONS BY MEMBERS OF THE UNIVERSITY OF KANSAS.

FIRST SUPPLEMENT.

THERE was published in this journal, series A, Volume VIII, No. 4, October, 1899, a bibliography of the scientific publications by members of the University of Kansas. In the present supplementary list this bibliography is corrected in a few places and brought up to date.

Aldrich, JOHN M.

B. S. (South Dakota Agricultural College, 1888); M. S. (same, 1891, and University of Kansas, 1893). Professor of Zoology and Entomologist of Agricultural Experiment Station, University of Idaho, 1893.

1892 — 1. A New Genus and Species of Tabanidæ; Psyche, pp. 236, 237, 1 fig.
2. New Species of Phora; Canadian Entomologist, pp. 142–146, figs.
3. The Systematic Position of the Diptera; Science, New York.
4. Revision of the Genera Dolichopus and Hygroceleuthus; this journal, pp. 1–26, 1 pl.
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12. On the Diptera of St. Vincent (Dolichopodidæ and Phoridæ); Trans. Ent. Soc. Lond., pp. 309–345 and 435–439.

1899—13. A Balloon-making Fly (published with L. A. Turley); Amer. Nat., pp. 809–812, with illustrations.
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Bailey, EDGAR HENRY SUMMERFIELD.

(Continued from vol. viii A, p. 140.)

1900—53. A Comparison of the Chemical Constituents and Nutritive Values of Native and Cultivated Grasses; Quar. Rep. Kans. St. Bd. Agric., March.

54. The New Chemical Laboratory of the University of Kansas; Science, N. S., xii, No. 313, Dec. 28, pp. 997–1001, fig. 6.

55. On the Softening of Public Water-supplies, with some Analyses of a Recent Process; Proc. Kans. Gas, Water and Elec. Lt. Assoc., pp. 18–26.

1901—56. Experiments on the Relative Heating Power of Coal and Illuminating Gas; Trans. Kans. Acad. Sci., xvii, pp. 35–38, fig 1.

57. A Laboratory Guide to the Study of Qualitative Chemical Analysis; 200 pp., (with H. P. Cady); P. Blakiston's Son & Co., Phila.

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(Continued from vol. viii A, p. 140.)

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1901 — 7. Blunder in Caring for Parts of a Body Intended for Chemical Examination; Medical Record, (New York.)

8. Action of Liquid Anhydrous Ammonia on Acid Chlorids and Esters; this journal, x, pp. —— (with D. F. McFarland).

Beede, JOSHUA WILLIAM.

(Continued from vol. viii A, p. 140.)

1897—1*a*. Stratigraphy of Shawnee county; Trans. Kans. Acad. Sci., xv, pp. 27–34.

1899 — 9. Description of Some New Forms of Pseudomonotis from the Upper Coal Measures of Kansas; this journal, viii, pp. 79–84, pls. viii, ix.

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1900—11. Two New Crinoids from the Kansas Carboniferous; this journal, ix, pp. 21–24, pl. v.

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Blackman, MAULSBY WILLETT.

A. B. (University of Kansas, 1901).

1901 — 1. Spermatogenesis of the Myriapods, I; this journal, x A, pp. 61–76.

Blake, LUCIEN IRA.

(Continued from vol. viii A, p. 141.)

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Cady, HAMILTON PERKINS.

(Continued from vol. viii A, p. 142.)

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Crane, WALTER RICHARD.

A. B. (University of Kansas, 1895, and A. M., 1896); Ph. D. (Columbia, 1901). Instructor, Lawrence High School, 1896–'97; Beloit High School, 1897–'98; Instructor of Manual Training, city schools, Janesville, Wis., 1898–'99; Assistant Professor of Mining, 1899.

1896 — 1. Curvimeter; this journal, iv, p. 121.
2. Horsebacks in the Kansas Coal Measures; this journal, iv, p. 145.

1898 — 3. Special Report on Coal; Univ. Geol. Surv. Kans., iii, part 2, pp. 107–313.
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1901 — 5. Slime Treatment; Mines and Minerals, 1901, p. 465.
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Diemer, HUGO.

M. E. (Ohio State University, 1896). With Bullock Electric Manufacturing Company, Cincinnati, and Westinghouse Electric and Manufacturing Company, Pittsburg, 1896–'99; in charge of Mechanical Department A. and M. College, Greensboro, N. C., 1899–1900; Assistant Professor of Mechanical Engineering, Michigan Agricultural College, 1900–'01; Associate Professor of Mechanical Engineering, 1901.

1900 — 1. The Purchasing Department; Eng. Mag.
2. The Classification of Shop Orders; Eng. Mag.
3. The Production Department: Bills of Material; Eng. Mag.
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5. The Production Department: The Execution of the Work; Eng. Mag.
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Dyche, LEWIS LINDSAY.

(Continued from vol. viii A, p. 141.)

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Franklin, Edward Curtis.

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14. Ionic Velocities in Liquid Ammonia (with H. P. Cady). Read at Pittsburg meeting of A. A. A. S.

Harris, J. Arthur.

A. B. (University of Kansas, 1901). Graduate Student, University of Kansas, 1901; Botanical Assistant, Missouri Botanical Garden, 1901.

1900 — 1. Annotated Catalogue of the Crayfishes of Kansas; this journal, ix A, pp. 263-274.

2. Annotated Catalogue of the Crayfishes of Kansas (abstract); Trans. Kans. Acad. Sci., xviii, p. 115.

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Ph. C., 1893, Ph. M., 1894 (University of Michigan). Assistant in Pharmacy and Pharmacognosy, University of Michigan, 1893-'94; Analytical Chemist with Dr. A. B. Lyons, Honolulu, H. I., 1894-'95; Pharmacist with J. B. Chase, Aurora, Ill., 1895-'96; Chemist with the Chicago & Aurora Smelting and Refining Company, Aurora, Ill., 1896-'99; Assistant Professor of Pharmacy, University of Kansas, 1899.

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A. B. (University of Kansas, 1900). Instructor in Chemistry, 1901.

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Powell, EMERY H.

B. M. E. (University of Wisconsin, 1891). Draftsman and Erecting Engineer for the Hercules Ice Machine Company, Aurora, Ill., 1892–'96; Chief Draftsman and Assistant Superintendent Jobbins & Van Ruymbeke (manufacturers glycerine machinery), Aurora, Ill., 1896–'99; Draftsman and Designer of Beet-sugar Machinery with the Dayton Globe Ironworks Company, Dayton, Ohio, 1899–1900.

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Rogers, Austin Flint.

A. B. (University of Kansas, 1899); A. M. (1900). Graduate Student and Assistant in Mineralogy 1899–1900; Assistant Geologist, University Geological Survey of Kansas, 1898–'00; Fellow in Mineralogy, Columbia University, New York city, 1900–'02.

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Sellards, E. H.

A. B. (University of Kansas, 1899); A. M. (1900). Assistant, University Geological Surveyor of Kansas, 1900, 1901; Graduate Student Yale University, 1901.

1900—1. Note on the Permian Flora of Kansas; this journal, ix, pp. 63-65.
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A. B. (Kansas University, 1900); A. M. (1901). Instructor in Zoölogy, Kansas University, 1899; Instructor in Zoölogy and History, 1900; Fellow in Zoölogy, Columbia University, 1901.

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Ward, Frank E.

Superintendent of Fowler Shops and Shop Instructor; Instructor in Machine Work and Mechanical Methods and Practice.

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Colorado Springs, Colorado College. Studies.
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CONNECTICUT.

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New Haven, Yale Medical Journal, Yale Scientific Monthly.
——— Connecticut Academy of Sciences. Transactions.

DISTRICT OF COLUMBIA.

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——— American Monthly Microscopical Journal.
——— Biological Society of Washington. Proceedings.
——— Entomological Society of Washington. Proceedings.
——— Mathematical Magazine.
——— Philosophical Society of Washington. Bulletin.
——— Smithsonian Institution. Publications.
——— United States Naval Observatory. Publications.
——— Commissioner of Education. Publications.
——— United States Department of Agriculture. Publications.
——— United States Geological Survey.
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GEORGIA.

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——— Field Columbian Museum. Publications.
——— The Irrigation Age.

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——— Western Society of Engineers. Journal.
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——— Indiana Geological Survey. Annual Reports.

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——— Iowa Academy of Sciences. Proceedings.
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——— Minnesota Academy of Natural Sciences. Bulletin.

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——— Nebraska Historical Society. Proceedings and Transactions.

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PENNSYLVANIA.

Bryn Mawr, Bryn Mawr College. Publications.
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——— Engineers' Club of Philadelphia. Journal.
——— University of Pennsylvania. Publications.
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——— Wagner Free Institute of Science. Transactions.
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——— Museo Nacional de Buenos Aires. Anales, Communicaciones.
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Rio de Janeiro, Museu Nacional. Archivas.
——— Sociedad de Geografia de Rio de Janeiro. Revista.
Para, Museu Paraense. Boletin.
Sao Paulo, Museu Paulista. Revista.

CHILI.

Santiago, Sociedad Cientifica. Alemana, Verhandlungen.
——— Sociedad Cientifica de Chile.
——— Universidad de Chile. Anales.

URUGUAY.

Montevideo, Museu Nacional de Montevideo. Anales.

AUSTRIA.

nsbruck, Tiroler Landes-Museum Ferdinandeum. Zeitschrift.
Cracow, Academie des Sciences. Bulletin International.
Lemberg, Academie der Wissenschaften. Chronik.
Prag, Böhmische Mathematische Gesellschaft. Casopis, Sbornik.
——— Böhmische Gesellschaft der Wissenschaften. Jahresberichte, Sitzungsberichte Mathematische und Naturwissenschaftliche Klasse.
Vienna, K. K. Geologische Reichsanstalt. Verhandlungen, Jahrbuch.
——— Monatshefte für Mathematik und Physik.
——— Naturwissenschaftlicher Verein der Universität Wien. Mittheilungen.
——— K. K. Naturhistorisches Hof Museum. Annalen.
——— K. K. Zoologisch-Botanische Gesellschaft. Verhandlungen.
——— Kaiserliche Akademie der Wissenschaften. Sitzungsberichte.

BELGIUM.

Brussels, Académie Royal des Sciences, des Lettres et des Beaux Arts de Belgique.
——— Société Royale Malacologique. Annales, Proces-Verbaux.
——— Société Entomologique de Belgique. Annales.
——— Société Belge de Géologie, de Paléontologie, et d' Hydrologie. Bulletin.
——— Université de Bruxelles. Revue.
Liége, Société Géologique de Belgique. Annales.
Louvrain, La Cellule.
——— Société Scientifique de Bruxelles. Annales, Revue des Questions Scientifique.

DENMARK.

Copenhagen. Nyt Tidsskrift for Mathematik.

ENGLAND.

Cambridge, Cambridge Philosophical Society. Proceedings, Transactions.
Hull, Scientific and Field Naturalists' Club. Transactions.
Halifax, Yorkshire Geological and Polytechnic Society. Proceedings.
Leeds, Yorkshire Naturalists' Union. Transactions.
Liverpool, Biological Society. Proceedings and Transactions.
London, British Museum (Natural History Department). Catalogues.
——— Geological Society. Quarterly Journal.
——— Royal Society. Proceedings.
Manchester, Literary and Philosophical Society. Memoirs and Proceedings.
Newcastle, Institute of Mining and Mechanical Engineers.
Tring, Zoological Museum. Novitates Zoologicæ.
York, Yorkshire Philosophical Society. Annual Reports.

FINLAND.

Helsingfors, Société de Géographie de Finlande. Finnia.
——— Sociatas pro Fauna et Flora Fennica. Acta, Meddelanden.
——— Geografiska Föreningen i Finland. Meddelanden.
——— Société des Sciences de Finland. Acta, Ofversigt af Forhandlingen.
——— Commission Géologique de la Finland. Bulletin.

FRANCE.

Amiens, Société Linnéenne du Nord de la France. Memoires, Bulletin.
Cherbourg, Société des Sciences Naturalles et Mathematiques.
Dijon, Académie des Sciences, Arts, et Belles-lettres. Memoires.
Lille, Université de Lille. Travaux et Memoires.

Marseilles, Faculté des Sciences de Marseille. Annales.
Montpellier, Académie des Sciences et Lettres. Memoires.
Nancy, Societe des Sciences de Nancy. Bulletin.
Nantes, Société des Sciences Naturelles de l'Ouest de la France. Bulletin.
Paris, Musée d'Histoire Naturelle. Bulletin.
——— Bureau des Longitudes.
——— Nouvelles Annales de Mathematiques.
——— Académie des Sciences. Comptes Rendus.
——— Revue Critique de Paliozoologie.
——— Société Philomateque de Paris. Bulletin.
——— Société de Geographie. Bulletin, Comptes Rendus.
——— Feuilles des Jeunes Naturalistes.
Toulouse, Académie des Sciences. Inscriptions, et Belles-lettres, Bulletin.
——— Université de Toulouse. Annales de Faculté des Sciences.

GERMANY.

Aachen, Meteorologische Station I. Ordnung, Berichte.
Berlin. Laboratorium und Museum.
——— Deutsche Physicalische Gesellschaft. Verhandlungen.
——— Naturæ Novitates.
——— Königliche Geologische Landesanstalt. Jahrbuch.
——— Deutsche Geologische Gesellschaft. Zeitschrift.
——— Deutsche Apotheker Verein. Arkiv der Pharmazie.
——— Entomologische Nachrichten.
——— Berliner Entomologischer Verein. Zeitschrift.
——— Königliche Preussische Akademie. Sitzungsberichte.
——— Prometheus.
——— Gesellschaft Naturforschender Freunde. Sitzungsberichte.
Braunschweig, Verein für Naturwissenschaft zu Braunschweig. Jahresberichte.
Darmstadt, Grossherzogliche Geologische Landesanstalt. Notizblatt, Verhandlungen.
Dresden, Verein für Erdkunde. Jahresberichte.
——— Naturwissenschaftliche Gesellschaft "Isis." Sitzungsberichte und Abhandlungen.
Erlangen, Physicalisch-Medizinische Societät. Sitzungsberichte.
Frankfort, Senkenbergische Naturforschende Gesellschaft. Berichte.
——— Physikalischer Verein. Jahrsberichte.
Giessen, Oberhessische Gesellschaft für Natur- und Heilkunde. Berichte.
Göttingen, Königliche Gesellschaft der Wissenschaften. Nachrichten.
Halle, K. L. C. Deutsche Akademie der Naturforscher. Nova Acta, Leopoldina.
Hamburg, Mathematische Gesellschaft zu Hamburg. Mittheilungen.
——— Naturwissenschaftlisher Verein. Abhandlungen.
Hildesheim, Roemer Museum. Mittheilungen, Berichte.
Kassel, Verein für Naturkunde. Berichte.
Königsberg, Physikalisch-Oekonomische Gesellschaft. Schriften.
Munich, K. Akademie der Wissenschaften. Sitzungsberichte.
Stuttgart, Mathematisch-Naturwissenschaftlicher Verein in Württemburg.
——— Verein für Vaterlandische Naturkunde in Württemburg. Jahreshefte.
Ulm, Verein für Mathematik and Naturwissenschaften. Jahreshefte.
Würzburg, Physikalisch-Medizinische Gesellschaft. Sitzungsberichte, Verhandlungen.

HOLLAND.

Amsterdam, Koninklijke Akademie van Wetenschappen. Verslag, Verhandelingen.
——— Genootschap der Mathematik Wetenschap. Wiskundige Opgaven, Nieuw Archief voor Wiskunde, Revue Semestrielle des Publications Mathematiques.
Haarlem, Musée Teyler. Archives.
Helder, Nederlandsche Dierkundige Vereenigung. Tijdschrift.
Rotterdam, Nederlandsche Entomologische Vereenigung. Tijdschrift.

HUNGARY.

Buda-Pesth, Ungarische Nationalmuseums. Természetrajzi Füsetek.
——— K. Ungarische Geologische Landsanstalt. Jahresbericht, Mittheilungen.
Presburg, Verein für Heil- und Naturkunde. Verhandlungen.

IRELAND.

Belfast, Queen's College. Publications.
——— Belfast Natural History and Philosophical Society. Report and Proceedings.

ITALY.

Bologna, R. Academia delle Scienze dell'Instituto di Bologna. Memoires.
Florence, Società Entomologica Italiana. Bullettino.
Genoa, Bullettino di Bibliografia e Storia della Scienze Matematica.
Milan, Annali di Matematica.
——— R. Instituto Lombardo di Scienze, e Lettere. Rendiconti, Memoires.
Modena, R. Accademia di Scienze, Lettre, ed Arti. Memoires.
Naples, R. Accademia di Scienze, Fisiche, e Matematiche. Rendiconti, Memoires.
Padua, R. Accademia di Scienze, Lettere, ed Arti. Atti e Memoires.
Palermo, Circolo Matematico di Palermo. Rendiconti.
Pisa, Società Toscana di Scienze Naturali. Atti.
——— Il Nuovo Cimento.
——— R. Scuola Normale Superiore. Annali.
Rome, R. Ufficio Geologico. Memoires, Bollettino.
——— Società Geografica Italiana. Bollettino.
——— R. Accademia dei Lincei. Rendiconti.
Turin, Museo di Zoologia e di Anatomia Comparata. Bollettino.
——— R. Accademia Reale delle Scienze. Atti.

NORWAY.

Bergen, Bergens Museum. Aarbog.
Christiania, K. Videnskabs Selskab. Skrifter, Forhandlinger.
——— Universitets, etc., etc. Archiv for Mathematik og Natur Jahrbuch des Nor.
Throndhjem, K. Norske Videnskabers Selskab. Skrifter.
Tromsö, Tromsö Museum. Aarshefter, Aarsberetning.

PORTUGAL.

Oporto, Jornal de Sciencias Mathematicas e Astronomicas.

RUSSIA.

Kasan, Societe Physico-Mathematique. Bulletin.
Kharkow, Societe Mathematique de Kharkow. Communications.
——— Societe de Naturalistes a l'Universite de Kharkow. Travaux de la Societe.
Moscow, Societe Mathematique de Moscow. Recueil Mathematique.
Nowo-Alexandria, Annuaire Geologique et Mineralogique de la Russie.
Riga, Naturforscher Verein.

St. Petersburg, Societe Imperial des Naturalistes de St. Petersbourg.
——— Landwirthschaftlich-Bacteriologischen Laboratoriums.
——— Societe Entomologique de Russie. Horae.
——— Academie Imperiale des Sciences. Bulletin.
——— Comite Geologique de Russie. Bibliotheque Geologique, Memoires, Bulletin.

SCOTLAND.

Edinburgh, Edinburgh Mathematical Society. Proceedings.
——— Royal Society of Edinburgh. Transactions, Proceedings.
Edinburgh, Edinburgh Geological Society. Transactions.
Glasgow, Natural History Society of Glasgow. Proceedings and Transactions.
——— Philosophical Society of Glasgow. Proceedings.

SERVIA.

Belgrade, Annales Geologique de la Peninsula Balkanique.

SPAIN.

Madrid, R. Academia de Ciencias Exactas, etc. Memoirs.

SWEDEN.

Göteborg, Kongl. Vetenskaps och Vitterhets Samhället. Handlinger.
Lund, Lunds Universitets Bibliothek. Arskrift.
Stockholm, Institut Royal Géologique. Afhandlingar och Uppsatser.
——— Entomolgiska Förenningen i Stockholm. Entomologisk Tidskrift.
——— Kongl. Vitterhets, Historie och Antiquitets Akademiens Bibliothek. Monadsblad, Antiquarisk Tidskrift.
——— K. Svenska Vetenskaps Akademien. Oefersigt af Förhandlingar.
Upsala, K. Universitet Upsala. Arskrift, Bulletin of the Geological Institute.

SWITZERLAND.

Bern, Schweizerische Entomologische Gesellschaft. Mittheilungen.
——— Scheizerische Gesellschaft für die Gesammten Naturwissenschaften. Verhandlungen, Neue Denkschriften.
Lausanne, Société Vaudoise des Sciences Naturelles. Bulletin.
Neuchâtel, Société des Sciences Naturelles. Bulletin.
——— Societe Neuchâteloise de Géographie. Bulletin.
Zürich, Schweizerische Geologische Commission. Geologischen Karte des Schweiz.
——— Naturforschende Gesellschaft in Zürich. Vierteljahrschrift.

AFRICA.

Cairo, Institut Egyptien. Bulletin, Memoires.
Cape Town, South African Philosophical Society. Transactions.
——— Geological Commission of Cape Colony. Publications.

ASIA.

Bombay, Royal Asiatic Society. Journal.
Calcutta, Geological Survey of India. Memoirs, Annual Reports.
——— Indian Museum. Notes.
——— Asiatic Society of Bengal. Journal.
Batavia, Koninklijke Naturkundige Vereening. Naturkundig Tijdschrift.
Buitenzorg, 's Lands Plantentuin. Verslag, Mededeelinge, Bulletin.
Tokyo, Societatis Zoologicæ Tokyonensis. Annotationes.
——— Imperial University of Tokyo. Journal of the College of Science.

AUSTRALASIA.

Sidney, The Australian Museum. Records, Memoirs, Annual Reports.
——— Australasian Association for the Advancement of Science. Reports.
——— Department of Mines. Records, Memoirs, Mineral Resources.
Brisbane, Royal Society of Queensland. Proceedings.
Adelaide, Government Astronomer. Meteorological Observations.
——— Royal Society of South Australia. Transactions.
Melbourne, Royal Society of Victoria. Proceedings.
Perth, Government Geologist. Annual Reports, Special Reports, Bulletins.

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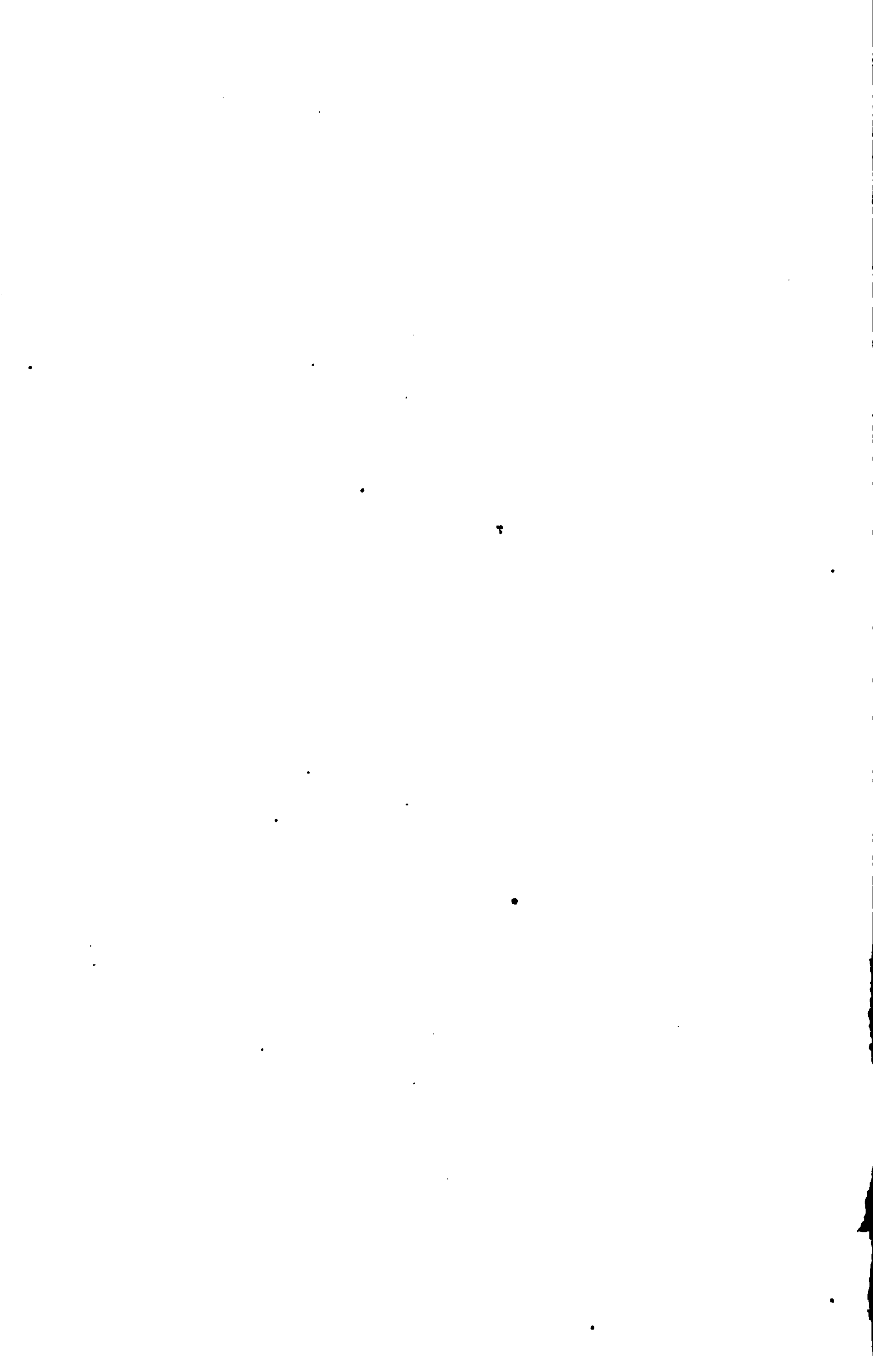
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